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PRACTICAL CONCRETING

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ENGLISH UNIVERSITIES PRESS LTD.
LONDON

First printed 1919

Printed in Great Britain for the English Universities Press, Limited,
by Richard Clay and Company, Ltd., Bungay, Suffolk

PREFACE

THIS book is intended primarily for the use of students of Architecture, Building, Civil, Municipal, and Structural Engineering. It provides an introduction to the basic principles involved for practical concrete work, from the manufacture of Portland cement up to and including the finished concrete product.

It is also hoped that the book will be helpful to junior engineers, building foremen, clerks of works, etc., as a guide or for reference in their daily duties.

An attempt has been made to put matters into everyday language and to avoid highly technical terms.

The last chapter will, it is hoped, be found of assistance to the layman who desires to concrete his garden paths, garage floor, etc.

No attempt has been made to deal with reinforced-concrete design, since many excellent textbooks specializing in this subject already exist. Only the elementary basic principles have been introduced, but later chapters are devoted to work of a special character, such as coloured concrete, special cement finishes, precautions to be taken against frost, etc.

Introductions are given to the principles of pre-stressed concrete, vacuum concrete, and light-weight concrete.

A glossary of terms used in connection with concrete work is incorporated at the end of the book.

The author desires to acknowledge the assistance freely rendered by The Cement & Concrete Association and to express his thanks for permission to reproduce many tables, illustrations, etc., from their various publications.

Thanks are also due to the British Standards Institution

for permission to reproduce certain extracts from B.S. Code of Practice 114 : 1948, and acknowledgment is made to the following firms for permission to publish data and illustrations of their various plant and machinery :—

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CHAPTER I

MATERIALS USED FOR CONCRETE

Introduction

Concrete is made by binding together particles of sand and gravel, stone or broken brick, etc. The binding agent used is a paste of Portland cement and water, in suitable proportions.

When water is added to the cement, hydration takes place. This causes the whole mixture to set and harden, thereby forming a solid, rock-like mass.

The sand, gravel (or broken stone), etc., is termed " aggregate "; sand is known as " fine aggregate ", and gravel, etc., as " coarse aggregate ".

The proportions of each, together with that of the cement, are varied according to the class of work concerned.

Only sufficient water should be used to enable the hydration (chemical action) to take place and to make the mixture easily workable; any excess is detrimental to the ultimate strength of the concrete.

After depositing the wet concrete into the desired position, it should be well rammed or tamped, in order to consolidate it thoroughly and thereby obtain a dense mixture, which, after setting and hardening, will form a rock-like mass with no apparent voids.

Portland Cement (Ordinary Grade), General Description

Portland cement is a chemical product of fine grey powder form. It is made from chalk or limestone, and clay or shale, which are ground and mixed with water to form a paste—known as " slurry ". The mixture is then " burnt " or " calcined " in a kiln, from which it emerges in the form

of small, hard lumps, about the size of peas, and in that form it is known as cement "clinker".

The clinker is next ground to powder in "tube mills", which are large steel cylinders charged with hard steel balls for the grinding media. During the grinding a small percentage of raw gypsum is added, because this has the effect of retarding the setting time of the cement, thereby providing time for work to be performed in placing the concrete, levelling it, etc.; otherwise it would set too quickly.

Portland Cement Manufacture (Ordinary Grade)

For general purposes, ordinary Portland cement is far more commonly used than any other type of cement. The bulk of cement made in England is made from chalk and

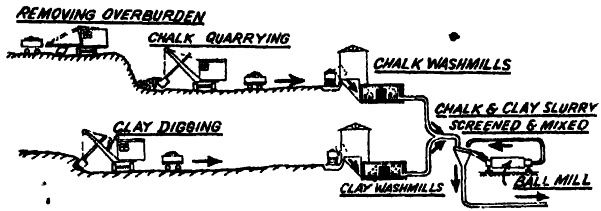

FIG. 1.—RAW MATERIALS PLANT

clay, and a brief outline of the manufacturing process is given forthwith.

On referring to Fig. 1 it will be seen that at the chalk quarry the "overburden" (turf, shrubs, and soil) is first removed to a suitable depth, to expose the chalk face. Here the chalk is excavated, usually by a mechanical digger. It is next conveyed in lump form to the chalk "washmills", where it is mixed with water, which process breaks it down so as to form a thin paste or "slurry".

The other raw material—clay—is also excavated from clay-pits and conveyed to the clay washmills, where it also is mixed with water and broken down to form a paste or slurry.

Note.—Although the method of conveying the chalk and clay from quarry to washmills, as shown in the diagram, is by rail wagons, it is sometimes performed by aerial ropeway, belt conveyor, or motor lorries, depending on site conditions, etc., and the distance of these raw materials from the cement works.

In both cases the washmills are merely large vertical cylindrical tanks, equipped with "agitators", which rotate, and, together with the action of the water, break down the chalk and clay, thereby forming a slurry.

The mixture, before being passed to the cement slurry storage tanks, is screened, and any large lumps are passed through a "ball mill" (a horizontal cylindrical steel drum, charged with heavy steel balls, which pulverize the large pieces), after which it is again screened before rejoining the washmills.

Next the cement slurry (i.e., a mixture of chalk and clay in thin paste form) is pumped to large storage tanks, where it is continuously agitated to prevent settlement.

Here the mixture is "rectified" (i.e., the percentages of chalk and clay are corrected) before being fed to the "kiln".

It might with advantage be mentioned here that the washmills and slurry storage tanks are equipped with agitators somewhat similar in principle to those used on sewage works—which no doubt some readers may have seen.

The mixture is next elevated to the kiln-feeder, which supplies a regulated quantity continuously to the rotary kiln. Any surplus from the feeder is returned to the storage tanks as seen in the diagram (Fig. 1*a*).

A rotary kiln for cement-making is a large steel tube or shell, with refractory lining, and equipped with suitable "lifters", fitted in certain sections. In some sections heavy steel chains are also suspended. The kiln is inclined axially, so that material fed into its higher end is automatically conveyed along during its rotation. Massive steel tyres or rings are fitted to the shell, and are mounted on steel rollers. The rollers are fitted to steel bed-plates,

which are supported by heavy concrete piers or pillars. The kiln is driven by a robust toothed gear-ring, from suitable gearing via an electric motor, as shown in the diagram (Fig. 1*a*).

At the lower end of the kiln—known as its firing end—coolers are attached outside the shell, and into these the clinker falls and is cooled prior to being fed on to a conveyor.

A cement kiln is usually fired by pulverized coal " dust ", which is blown into the kiln by a blast of air.

Referring back now to the slurry-feed end of the kiln, the liquid slurry, on being fed into the hot kiln, becomes heated

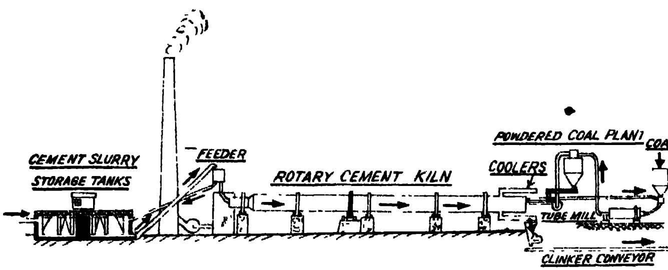

FIG. 1*a*.—CLINKER PLANT

and undergoes successive changes. First the water is evaporated ; next the calcium carbonate is decomposed into calcium oxide (or quick-lime) and carbon dioxide.

At a temperature of about 1,500° Centigrade incipient fusion occurs, and the components of the lime and clay combine, thereby forming calcium silicates, calcium aluminates, and other compounds, which together make up the cement clinker.

It will be realized by the reader that in a certain part of the kiln the liquid is changed into a solid. It is here that the chains and lifters alternately lift and drop the mixture during the formation of the clinker, in order to prevent it from caking or forming one solid mass.

This mixture, during its passage along the kiln, is

gradually being conveyed nearer and nearer to the hot end (firing end) where it becomes calcined—or "burned". Owing to the action of the lifters, the mixture is converted into small, hard lumps of about the size of a pea, called cement clinker.

As mentioned very briefly earlier, the cement clinker, just prior to being discharged from the kiln, passes through a series of "coolers". These coolers are small cylindrical drums attached to the outer perimeter of the kiln, and therefore rotate with it. Each cooler is also fitted with lifters, so that the clinker is automatically lifted and dropped during its passage along the cooler. Since the coolers are

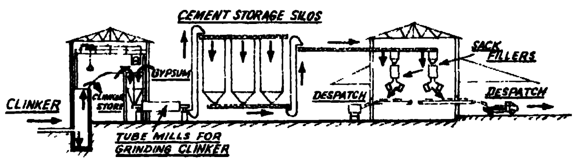

FIG. 1b.—CLINKER GRINDING, CEMENT STORAGE, AND BAGGING PLANT

subjected only to the atmosphere, the cool air gradually cools the clinker during its mechanical-handling treatment.

In order to give the reader some idea of the size and massive construction of a cement kiln, it may be mentioned that a modern kiln may range from 200 ft. long by 8 ft. diameter up to 400 ft. long by 12 ft. diameter.

After leaving the kiln the clinker is conveyed to the clinker store (see Fig. 1b).

In the diagram a crane is shown for reclaiming the clinker when required from the store, but some cement plants use certain types of conveyors both for feeding into and out of the store.

In its present form the cement clinker is now ready for grinding and converting into cement, but during the grinding a certain quantity—1 to 3 per cent.—of raw gypsum (calcium sulphate) is added, to prevent the cement from setting too rapidly when used (Fig. 1b).

"Tube mills" are employed for grinding the cement. These are heavy cylindrical steel drums, with chambered sections, in which are charges of heavy steel balls which, by their cascading action during the drum's rotation, pulverize the clinker into a fine grey powder—the finished cement (Fig. 1*b*).

The cement is then stored in large storage bins or silos, from whence it is extracted as required, to supply the packing plant, where it is usually packed into paper sacks by automatic machines. Cement is now often supplied by special lorries direct from the works in loose bulk form, ready for immediate use.

Portland cement is usually supplied in 1-cwt. paper sacks (unless for export, when it may be obtained in 1-cwt. or 2-cwt. airtight steel drums).

Cement readily absorbs moisture from the atmosphere (and consequently deteriorates quickly), so when supplied in paper sacks it must be stored until use in a very dry place, preferably on timber above ground level. This is very important, for once cement has been allowed to set and harden while in the bag it becomes useless for concrete. If, after opening a bag of cement, some is found to have "caked" and will not easily crumble to powder if squeezed between one's fingers, it should not be used.

In order to indicate the degree of fineness to which cement is ground, in a sample of ordinary grade Portland cement 95 per cent. will pass through a sieve having 32,400 holes per square inch.

"Rapid-hardening" Portland cement (to be described later) is ground to an even finer degree.

All brands of Portland cement which comply with British Standard Specification No. 12 are reliable.

The terms "setting" and "hardening" should not be confused, since the setting relates to the rate at which the cement paste stiffens, and hardening relates to the development of strength of the resulting concrete.

Rapid-Hardening Portland Cement

This is a special grade, which, although the setting time is similar to that of ordinary grade (i.e., thirty minutes minimum for the initial set, and not more than ten hours for the final set), acquires the same strength in one day as ordinary Portland cement does in three days. The difference in strength, however, diminishes with time, so that after twelve months the two grades have approximately the same strength.

Being ground to a finer degree, rapid-hardening cement is more expensive, but its extra cost is offset by work being completed more quickly, and, in addition, the contractor is able to dismantle shuttering more quickly, and thus release plant for use elsewhere.

Extra-Rapid-Hardening Cement

Another special grade of rapid-hardening cement is known as "417 cement", which is a quick-setting type and possesses extra rapid hardening qualities. It is claimed that concrete made with this "417" grade is ready for almost any duty twenty-four hours later. On all jobs where time is of vital importance the use of this cement can be a means of important savings in cost. It also gives greater productivity of plant, shuttering, etc.

Portland Blast-Furnace Cement

This consists of a finely ground mixture of Portland cement clinker and granulated blast-furnace slag. It is used in a similar manner to other ordinary cements, but not so extensively. It should comply with British Standard Specification No. 146.

Aluminous Cement (or High-Alumina Type)

Another special cement is the "aluminous", which differs considerably from the foregoing. The raw materials from which it is made are chalk and "bauxite".

The last-mentioned is an indurated clay containing a high percentage of alumina. Incidentally bauxite is also the basic mineral from which aluminium is manufactured.

In making aluminous cement the chalk and bauxite are mixed together in dry lump form and melted in a furnace at a very high temperature. The molten product is then cast into moulds, and after solidifying is broken up and ground into cement without the addition of any other ingredient. It is, however, not ground to quite the same degree of fineness as Portland cement.

Among the chief claims made for aluminous cement are its extraordinary immunity from chemical attack, its resistance to sea-water, sewage, oils, etc., and its suitability, when mixed with refractory materials, for furnace and chimney linings. It has the property of readily setting and hardening under water, for which purpose it is used extensively. Its setting time is from two to four hours for the initial set, and the final set is obtained about thirty minutes later.

Aluminous cement possesses remarkable rapid hardening qualities, and attains in twenty-four hours a compressive strength of about three times that of Portland rapid-hardening cement.

Concrete made from it must be kept wet during the first twenty-four hours, since, due to the cement's rapid-hardening qualities, considerable heat is evolved during its setting. It gives a very high early strength, and is more resistant than Portland cement to the action of sulphates which may be present in ground-waters, etc. The mix should never be richer than 1 : 2 : 4.

High-alumina cement should never be mixed with Portland cement, because it is NOT a Portland cement and, if mixed, the set would be greatly accelerated and the resulting product would be weakened.

It is manufactured to comply with the requirements of British Standard Specification No. 915.

Sand (or " Fine " Aggregate)

The sand used for making good concrete must be clean, coarse, and well graded—i.e., particles or grains must be of various sizes.

In concrete work the term " sand " is applied to all particles below $\frac{3}{16}$ in. in size; above that size it is called " coarse " aggregate.

The sand should be clean and free from clay, vegetable matter, etc., because when it is mixed with water and cement a chemical action takes place which causes the particles—also the aggregate—to bind together. Therefore, if impurities are present, the binding or adhesion is adversely affected.

If the sand is efficiently graded, the coarse type should predominate. This is because during its hydration the very fine particles of cement adhere to those of the sand, and this combination in turn adheres to the coarse aggregate. They are thus better enabled to fill up the spaces—or " voids ", as they are termed—between the coarse aggregate.

Therefore, if the sand used is too coarse and ungraded, the resulting concrete will be harsh and porous, instead of having a dense texture.

Conversely, if the sand is too fine and uniform, a larger quantity of cement will be required to " coat " thoroughly all the grains of sand. This is uneconomical.

The sand or fine aggregate used may be natural sand or that formed artificially by crushing gravel, stone, or other hard material which will pass through a $\frac{3}{16}$-in. B.S. sieve. Very fine " dust " should be eliminated.

Sand dredged from rivers and lakes is suitable if coarse and graded.

Desert sand—usually " wind-blown "—in most cases is unsuitable, on account of its being too fine and uniform in particle size. The same remarks also apply to material termed " building sand "—as used for brickwork mortar.

Sand specified for concrete work is sometimes described

as "sharp" (i.e., the grains are of angular formation), but recent experience has proved that excellent concrete can be made from sand of rounded particle shape.

Some indication of its suitability for concrete sand may be obtained by rubbing a damp sample between the hands and noting the staining effect on the palms. The stain will indicate the presence of clay or dirt, and the action of rubbing will demonstrate the sharpness.

More definite tests are dealt with later under that heading.

Aggregate

The term "coarse aggregate" applies to the remainder of the hard materials which are used to complete the solid ingredients for the concrete—such as gravel, shingle, crushed stone, granite, broken brick, etc.—and larger than $\frac{3}{16}$ in. in size.

It also should be well graded—i.e., it should contain a proportion of all sizes from $\frac{3}{16}$ in. upwards, to the largest specified for the work concerned.

For work of importance, clean, washed, crushed stone—such as gravel or granite—should be used, but for work of minor importance graded ballast—broken limestone, broken bricks, etc.—is sometimes used.

Ballast is the term usually applied to gravel or shingle dredged from rivers and pits which contain suitable proportions of sand. In this case it is rarely necessary to add further sand or fine aggregate.

Coke breeze and clinker may be used for coarse aggregate, provided they do not contain large amounts of sulphur or other deleterious matter. They are, however, not used for important work.

All aggregates must be free from clay, loam, or organic matter, and the shape should preferably be angular or rounded; flake-shaped materials should be avoided.

For plain concrete work not exceeding 6 in. in thickness the largest size of aggregate should never exceed $1\frac{1}{2}$ in., but for reinforced concrete—i.e., in which steel rods or

wire mesh are used to reinforce the work—the largest size of aggregate should be such as will penetrate between the reinforcements easily without displacing them. In most cases the size does not exceed $\frac{3}{4}$ in.

For mass concrete—i.e., heavy foundations, sea walls, dams, etc.—the aggregate size may be up to 3 or 4 in., and in certain cases even larger, but for the faces of such work it is usual to use sizes of $\frac{3}{4}$ in. up to $1\frac{1}{2}$ in. Towards the centre of very thick walls, dams, and foundations, large stones or boulders of 6–12 in. in size are sometimes deposited sparsely among the wet concrete during its casting. These are known as "plums", and form anchorage, in addition to effecting a saving of normal concrete. They should, however, be used with caution, since their effective spacing is attained only by long experience.

Water

Water is used to effect the chemical action in the cement—known as "hydration". It is this action which causes the cement to set and harden.

It will therefore readily be appreciated that only good, clean water must be used for concrete work, since water containing impurities may considerably affect the setting.

If river, lake, or stream water is to be used, care should be taken to ensure that it is suitable and does not contain decayed vegetable matter, etc.

In rural areas, water from rivers, streams, and ponds, which may contain stagnant water, liquid manure, etc., should be regarded with suspicion, and a small trial batch of concrete should be made, in order to try it out before concreting on a large scale is attempted.

Incidentally, referring to an occurrence some years ago during the construction of a large concrete job, after taking satisfactory samples, water was used from an apparently reasonably clean stream, and for a certain time concreting proceeded satisfactorily. Eventually, however,

after several weeks of successful concreting, the work was suddenly found not to be setting and hardening properly. The cement was at first suspected, but on inquiry being made at the cement factory it was found that no difference had been made during its manufacture. Samples were returned for investigation and tests were carried out, but with normal results.

Next, in turn, the sand and aggregate were again tested and found satisfactory.

However, when water samples were again analysed they were immediately found to contain some chemical not normally known to be present in the stream.

It transpired, on further investigations being made, that certain waste materials were occasionally deposited into a drain at a chemical factory several miles farther upstream. These eventually discharged into it.

It was also learned that only at certain periods during the year was this chemical used at the factory, hence the several days of successful concreting before the firm used the chemical.

Eventually it was decided to install a piped municipal water supply to the construction site. No further trouble was then experienced with the concrete.

All this indicates that several samples of water should be taken from streams at various times of the day and night before concreting starts, and samples should also be taken periodically during concreting.

As a general rule, stream or spring water fit for drinking, or water from a piped municipal supply, are suitable for concrete work.

The quantity to be used for various mixes is dealt with later.

Water–Cement Ratio (Explanation of)

The ratio $\dfrac{\text{weight of water in a mix}}{\text{weight of cement in a mix}}$ is known as the "water–cement" ratio—e.g., if a concrete mix contains

1 sack of cement (112 lb.), and the total water used is 7 gallons (70 lb.), then the water–cement ratio for that mix is $\frac{70}{112} = 0{\cdot}62$.

The more water added to the mix, the weaker becomes the resulting concrete.

A certain proportion of the water combines with the cement, which, due to the chemical action set up, hardens. The remaining water is required solely to provide a "workable" mix. The water eventually evaporates, thus leaving minute pores in the concrete. The greater the quantity of water used, therefore, the more porous the concrete will be, and the more water used in excess of that required to effect the chemical action, the weaker will the concrete be.

Proportioning of Materials

Having decided on the materials to be used for the work, attention must be directed to the proportions for the "mix".

It is usual to measure the ingredients by volume, by taking 1 cu. ft. of cement as a basis, especially for small jobs.

Incidentally, a 1-cwt. sack of cement contains approximately $1\frac{1}{4}$ cu. ft.

Proportioning therefore is the amount of sand, aggregate, and water used to each cubic foot of cement. As mentioned earlier, only sufficient water should be used to hydrate the cement and to make the mixture sufficiently plastic or workable. If too little water is used the mix is stiff and difficult to place or ram in order to compact it adequately. If machine-mixed, it is also difficult to discharge efficiently from the mixer drum.

On the other hand, when too much water is used (although, due to its "sloppiness", it is easily workable) the resulting concrete will be weakened. Furthermore, if the mix is very wet, on placing it in position the heavy aggregate settles to the bottom, and the lighter materials remain in suspension in the fluid which escapes between the shuttering

FIG. 2

Portland Cement Concrete

SUGGESTED MIXTURES FOR SEVERAL CLASSES OF CONSTRUCTION

For ordinary Portland cement concrete, compacted by hand. The sand is assumed to be damp. The quantity of water given is the actual Imperial gallons to add per batch, and should not normally be exceeded.

The Table is based on loose cement weighing 80 *lb. per cu. ft., damp sand* (30 *per cent. bulked*) 84 *lb. per cu. ft., broken stone* 90 *lb. per cu. ft.*

Mix.	For a one bag batch.				Approx. by volume for small jobs.				Quantities required per cu. yd. of concrete.					
	Cemt. (bags) (cwt.).	Sand (damp) (cu. ft.).	Coarse agg. (cu. ft.).	Water (net) (gals.).	Cemt. (loose) (pails).	Sand (damp) (pails).	Coarse agg. (pails).	Water (net) (pails).	Type of coarse aggregate.	Cemt.	Sand (damp)		Coarse agg.	
										lb.	cu. yd.	ton.	cu. yd.	tons.
A	1	5	7½	6	1	4	6	¾	Shingle Stone	335 370	0·54 0·59	0·55 0·60	0·83 0·91	1·09 0·99
B	1	4	6¼	5½	1	3¼	5	between ¾ and ½	Shingle Stone	392 432	0·52 0·58	0·53 0·59	0·81 0·89	1·06 0·96
C	1	3¼	5	5*	1	2½	4		Shingle Stone	481 524	0·51 0·56	0·52 0·57	0·79 0·86	1·04 0·93
D	1	2½	3¾	4½*	1	2	3		Shingle Stone	596 653	0·48 0·52	0·49 0·53	0·74 0·80	0·97 0·87
E	1	1½	2½	4	1	1¼	2	½	Shingle Stone	813 880	0·43 0·47	0·44 0·48	0·67 0·72	0·88 0·78

* *Increase slightly for reinforced concrete if not fluid enough for easy placing around reinforcement.*

B B Mukherjee

Mix.	Class of work suitable for
A	Roughest type of mass concrete, such as footings under walls of farm buildings, etc.
B	Mass concrete of better class than A, such as bases for machinery, walls below ground, etc.
C	Most ordinary uses of concrete (usually specified 1 : 2 : 4), such as mass walls above ground, road slabs, etc., and general reinforced concrete work.
D	Watertight floors, pavements and walls, tanks, pits, steps, paths, surface of 2-course roads, reinforced concrete where extra strength is required, medium and large fence posts.
E	Work of thin section, such as small fence posts and small pre-cast work.

NOTE :—If the proportions suggested do not give a " workable mix " with the materials used vary slightly the quantities of sand and coarse aggregate, *but do not add more water, except in the case noted above.*

MAXIMUM AGGREGATE SIZE :—For all reinforced concrete the coarse material should be graded from ¾ in. to $\frac{3}{16}$ in. For plain concrete the largest particles of coarse material should not be greater in diameter than one-quarter of the thickness of the work : Maximum sizes usually suitable are Mix A—2½ in. ; mix B—2 in. ; mix C—1 in. (roads 1½ in.) ; mix D—¾ in. ; mix E—½ in. (or less if work is very thin). All sand should be graded from $\frac{3}{16}$ in. down with a good proportion of the larger particles.

PRECAUTIONS. Use a British-made cement, clean sand, clean coarse material, and clean water. Do not use too much water; the drier the mix, provided it is workable, the better the concrete. Measure the materials, and mix them thoroughly both before and after adding the water. Place the concrete within 30 minutes of mixing; tamp and spade it well. Protect the concrete from sun and wind and keep it damp for 10 days. Do not undertake concrete work in frosty weather.

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or overflows, and carries with it a certain amount of cement, thereby losing its benefit.

Cement is usually the most expensive ingredient, so the use of excessive water becomes uneconomical, in addition to making the concrete weak.

Concrete should be of sufficient strength for whatever purpose it is intended. It is unnecessary and uneconomical to make it stronger.

A certain mix might be suitable for one particular job yet totally unsuitable for another. For instance, if a concrete foundation is required on which to erect a certain machine, a mix of 1 part of cement, 2 parts of graded sand, and 4 parts of coarse aggregate might be used, to which would be added the requisite amount of water (see Fig. 2).

This would be termed a six-to-one mix—i.e., 6 parts of aggregate (coarse and fine) to 1 part of cement, all being measured by volume.

That is quite a popular mix, and should produce good-quality concrete.

If, however, instead of using *graded* sand and aggregate in the above-mentioned proportions, it is decided to use "all-in" ballast or shingle (which contains sand in *approximately* the correct proportion), then 5 parts of ballast would be used to 1 part of cement.

Note.—The difference in quantities of six and five for the aggregate is made to allow for any inequality or variation of the sand content in the ballast.

Another popular mix—but used for high-class work, especially reinforced-concrete buildings—is 1, 1½, 3 (i.e., 1 part of cement and 1½ parts of graded sand, to 3 parts of well-graded coarse aggregate). This produces a very high quality concrete if properly mixed.

Whatever mix is specified or decided upon for any particular job, "gauge-boxes" should be used in order to measure accurately the quantities.

Gauge-Boxes (Use of)

Let it be assumed that a 1–2–4 mix has been decided upon for a specific job.

It would then be necessary to construct a wooden box of 1 cu. ft. capacity in which to gauge (measure) the cement. It is preferable to use this solely for cement, since it can then be kept dry; sand and aggregates (as delivered to a site) are frequently wet or damp, as a result of washing or from dredging.

A second box should therefore be made of 2 cu. ft. capacity, for gauging the sand and aggregate.

For the above-mentioned mix the cement box would be filled level with cement; then the box having 2 cu. ft. capacity would be filled *once* with sand.

Hand-Mixing

Its contents (if for hand-mixing) would be deposited on to a mixing-board (or a clean floor); the contents of the cement box would next be emptied over the sand, and by hand shovelling the materials thoroughly mixed.

The 2-cubic-feet-capacity box would then be filled *twice* with coarse aggregate—e.g., to produce *4 cu. ft.*—and its contents deposited on the mixing-board.

Next the whole ingredients (cement, sand, and coarse aggregate) should be thoroughly mixed together, and as evenly as possible, *before* adding any water.

After thoroughly mixing the dry materials, water should be added gradually, preferably by using a water-can equipped with a rose-type spray.

The quantity of water used must also be measured accurately for each mix, and during its application the heap of materials should constantly be turned over by shovelling.

Note.—For hand-mixing for small jobs it is advisable to add 10 per cent. more cement.

Water–Cement Ratio (Application)

As previously mentioned, if too little water is applied to the mix the resulting concrete will be harsh or "honeycombed", by preventing the voids (hollow spaces between

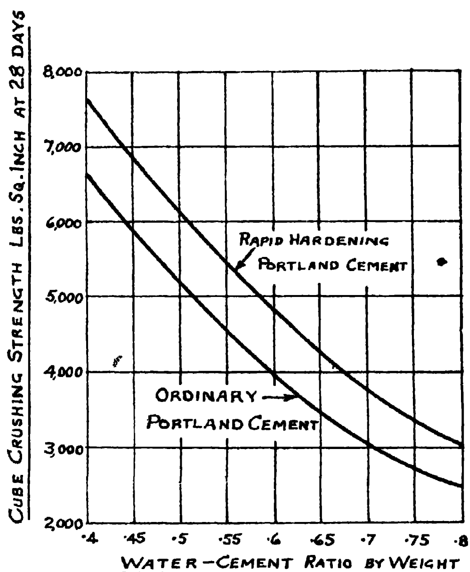

FIG. 2*a*.—WATER-CEMENT RATIO RELATED TO CRUSHING STRENGTH

the large aggregate) from being filled efficiently by the cement and sand particles in paste form.

The correct water–cement ratio should be used consistent with the types of aggregate and sand employed, also for the class of work concerned (see Fig. 2*a*).

In order to predetermine this, small trial batches of concrete may be made and the water carefully measured.

In practice, the water content of concretes can be compared and controlled by making "slump tests", for which an instrument called a "slump cone" is employed. This is described fully later under the heading "Testing".

The mix should also be a workable one, but no attempt must be made to improve the workability by adding more water.

A "Workable" Mix

The question may now be asked, "What is a workable mixture?" For concrete that is to be compacted by hand (as opposed to compacting by mechanical vibration or other methods) a workable mixture is one of such plasticity and degree of wetness that it can readily be placed in the forms

FIG. 2b

Mix Proportions (by Weight) Required to Give Different Degrees of Workability with Different Values of Water–Cement Ratio

Workability.	W.-C. ratio.	Gravel aggregate.		Crushed rock aggregate.	
		¾ in.	1½ in.	¾ in.	1½ in.
Very low slump 0–1	0·4	1 : 4·8	1 : 5·3	1 : 4·5	1 : 5
	0·5	1 : 7·2	1 : 7·7	1 : 6·5	1 : 7·4
	0·6	1 : 9·4	1 : 10	1 : 7·8	1 : 9·6
	0·7	1 : 10	1 : 12	1 : 8·7	1 : 10·6
Low slump 1–2	0·4	1 : 3·9	1 : 4·5	1 : 3·5	1 : 4
	0·5	1 : 5·5	1 : 6·7	1 : 5	1 : 5·5
	0·6	1 : 6·8	1 : 7·4	1 : 6·3	1 : 7
	0·7	1 : 8	1 : 8·5	1 : 7·4	1 : 8
Medium slump 2–4	0·4	1 : 3·5	1 : 3·8	1 : 3·1	1 : 3·6
	0·5	1 : 4·8	1 : 5·7	1 : 4·2	1 : 5
	0·6	1 : 6	1 : 7·3	1 : 5·2	1 : 6·2
	0·7	1 : 6·8	1 : 7·9	1 : 6·2	1 : 7
High slump 4–7	0·4	1 : 3·2	1 : 3·5	1 : 2·9	1 : 3·3
	0·5	1 : 4·4	1 : 5·2	1 : 3·9	1 : 4·6
	0·6	1 : 5·4	1 : 6·7	1 : 4·7	1 : 5·7
	0·7	1 : 6·2	1 : 7·4	1 : 5·5	1 : 6·5

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(shuttering), and such that with spading or tamping it will result in a dense concrete. In a workable mixture there should be sufficient cement-sand mortar to give good, smooth surfaces, free from rough spots—called " honeycombing "—and to bind the pieces of coarse aggregate into a mass, so that they will not separate out in handling.

A workable mixture for one class of work may be too stiff for another. Concrete for depositing in thin sections—such as reinforced-concrete walls—must, of course, be more plastic than that used for heavier work.

Very wet or sloppy mixtures are to be avoided at all times, since they segregate badly and result in weak, porous concrete (see Fig. 2*b*).

Laitance, Segregation, and Tamping (or Ramming)

Excess water in a mix may cause " segregation " and " laitance " ; the latter is a watery scum which may appear on the top of concrete when placed in the shuttering, and is caused by the settlement of the heavier particles. It should be removed, otherwise the concrete will be weak at this point and on hardening will form surface hair cracks.

Over-tamping sloppy mixtures causes the heavier particles to sink ; this is called " segregation ". This, of course, is undesirable.

On the other hand, insufficient tamping of drier mixes may leave empty spaces in the resulting concrete, causing " honeycombing ".

It is therefore essential to mix thoroughly and evenly all ingredients, so that every " void " is filled and every particle of sand and coarse aggregate coated with cement.

It is with this end in view that 10 per cent. more cement is often used for hand-mixing methods, so as to ensure the efficient coating of all ingredients used.

Gauging for Machine Mixing

Where a mechanical concrete mixer is to be used (instead of hand-mixing), the charging hopper (or skip) can be

sub-divided by fixing a division plate vertically across it and in a suitable position to provide two chambers for the sand and coarse aggregate respectively. Moreover, if the machine skip is of suitable size it is often convenient to use a 1-cwt. bag of cement as the basis instead of using a 1-cubic-foot box.

In this case—still maintaining the 1–2–4 mix previously considered—the skip-partitioned chambers must be $2\frac{1}{2}$ cu. ft. (for sand) and 5 cu. ft. (for the coarse aggregate), since the bag of cement contains $1\frac{1}{4}$ cu. ft.

Note.—Batching of aggregate by weight is now becoming popular, and automatic machinery is available for this method.

This system is suitable for large batch-mixing plants, especially where the cement is supplied in 1-cwt. bags, and also for bulk cement supplies (i.e., loose cement delivered direct from the factory in special covered-in lorries).

Batching plants are now used extensively with high-level storage and mixing facilities whereby lorries can load from overhead chutes. Such plants are used in industrial areas for supplying ready-mixed concrete to jobs within a reasonable distance for transportation.

Ready-mixed concrete is described more fully later.

In large concrete mixers the water is usually supplied from a cistern positioned on the machine and equipped with suitable cut-off valves for regulating the quantity. The cistern discharges directly into the mixer-drum, and is kept constantly supplied from a piped water supply.

If the machine is not fitted with a cistern, the operator feeds the water by hand for each mix from a measured quantity in a bucket, after the dry materials have previously been mixed in the rotating mixer-drum. Water is usually supplied to small machines in this manner.

Note.—Watch should be kept to ensure that supplies of both sand and aggregate arriving at site do not contain undue quantities of water. Should this be the case, the

water added to the mixer-drum must be reduced in order to compensate for this.

Tests for water content in sand are dealt with later.

Tools Used for General Work

Hand-mixing of small quantities of concrete should be performed on a clean floor—brick or concrete for preference. If the latter is not available, a mixing-board should be constructed, say 6 or 8 ft. square.

Mixing-Board

This should be composed of 1-in. or $1\frac{1}{4}$-in.-thick tongue-and-grooved boards, well battened on the underside to pro-

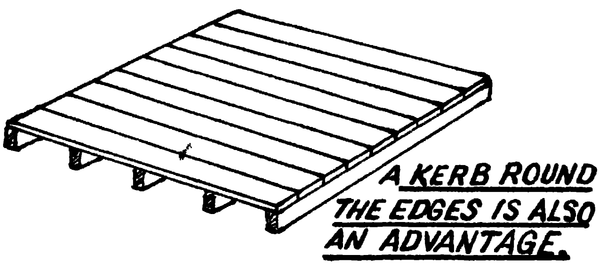


FIG. 3.—MIXING-BOARD

vide rigidity. The boards should not be painted or creosoted, but should be planed smooth to facilitate shovelling when mixing (see Fig. 3).

Gauge-Boxes (Construction)

For cement, a box having 1 cu. ft. internal capacity should be constructed, of 1-in.- or $1\frac{1}{4}$-in.-thick boards. Handles should be provided to facilitate depositing the cement.

As indicated earlier, the sizes of the boxes used for sand and coarse aggregate depend on the specified mix. In the example given of the 1–2–4 mix it was convenient to have only one box to be used *once* for sand, and *twice* for the

aggregate (unless, in order to expedite work, separate boxes are desired for the aggregate).

However, in the case of a 1–2½–4 mix it is essential to construct separate boxes for each capacity (Figs. 4 and 4*a*).

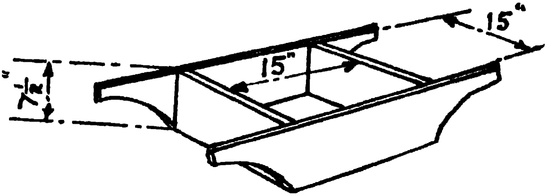


FIG. 4.—CEMENT BOX (1 CU. FT.

Note.—For small domestic jobs of minor importance—garden paths, garage floors, etc.—buckets will suffice for gauging, especially if a 1–2–4 mix is used. Moreover, further improvised tools, to be described later, may also be

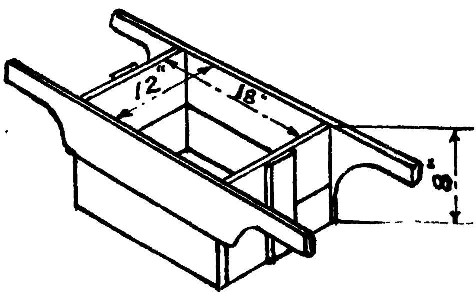


FIG. 4*a*.—AGGREGATE AND SAND BOX (2 CU. FT. CAPACITY)

employed, as alternatives to those used for professional work.

Fig. 5 depicts a concrete-mixer loading hopper, partitioned and marked for measuring fine and coarse aggregate. The dividing plate may be spot-welded or bolted to the hopper. In order to indicate the height to which the chambers must

be filled, battens composed of flat steel plates are bolted to the inner sides of the hopper.

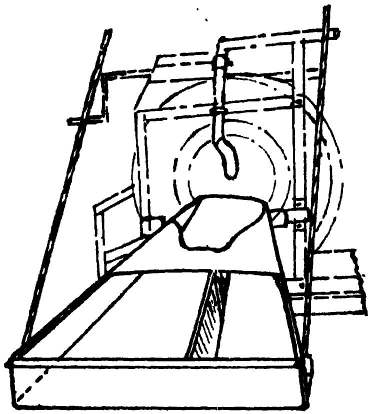


FIG. 5.—PARTITIONED LOADING HOPPER

Concrete Rammer (or Punner)

For compacting the concrete by manual methods a "punner" or "rammer" is used. Typical illustrations of

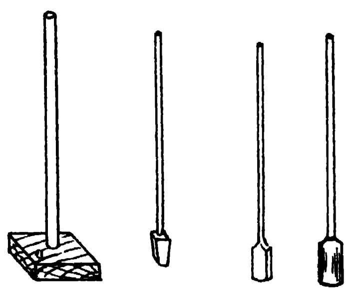


FIG. 6.—HAND RAMMERS

these are shown in Fig. 6. For reinforced-concrete work, however, plain round steel bars are used to ram the concrete

well between the reinforcements, especially in corner positions, the access to which for other types would be difficult.

Finishing Trowels, Floats, etc.

In order to smooth-off or finish concrete work after placing

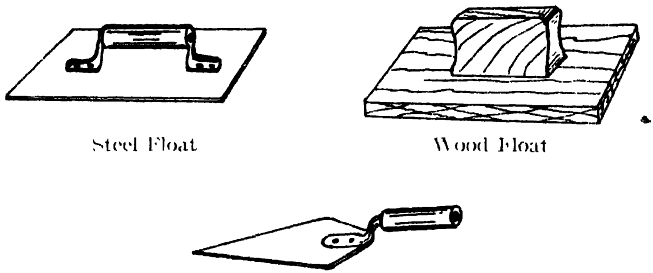


FIG. 7.—HAND TOOLS FOR CONCRETE WORK

and compacting it, steel floats and trowels are used. Various types are shown in Fig. 7.

Concrete Vibrators

In order to replace hand-ramming, mechanical vibrators are now used extensively for compacting concrete. This is especially so for reinforced-concrete work, such as walls, and for making mass-produced pre-cast units, such as road kerbs, fence-posts, piles, etc.

The vibrators may be operated either electrically or by compressed air, from flexible tubing. The tool (vibrating spade) is suspended in the wet concrete between the shuttering and reinforcements (if for walls). Other types can be attached direct to the shutters. By these methods more uniform compaction is obtained. Moreover, mixes containing less water are usable, thereby resulting in a better concrete than is often obtained by hand ramming.

Typical vibrators are shown in Fig. 8, and Fig. 8*a* shows one in use for vibrating concrete between wall shutters.

Fig. 9 depicts a mechanical hammer used for consolidating concrete by its action on the outer faces of shuttering.

A further interesting portable vibrator is the "Johnson" immersion type, model III, shown in Fig. 10, which may be operated by either a 4-h.p. petrol engine or an electric motor. Flexible shaft lengths up to 36 ft. can be operated, and 10,000 vibrations per minute can be provided by this machine; alternative needle diameters can be used. Three

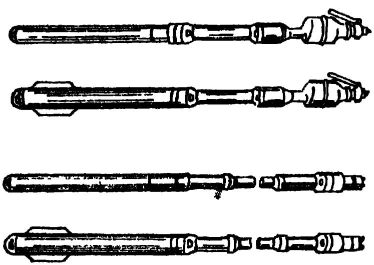


FIG. 8.—VIBRATING SPADES

FIG. 8*a*.—VIBRATING SPADE IN USE

sizes of needles are obtainable for this machine: $1\frac{1}{2}$-in.-, $2\frac{3}{8}$-in.-, and $3\frac{1}{2}$-in.-diameter.

Fig. 10*a* shows the $3\frac{1}{2}$-in.-diameter needle, in section. The principle of operation is that power, supplied from either a small petrol engine or an electric motor, rotates a flexible shaft fitted inside a flexible casing. The end of the shaft is coupled to an "out-of-balance" rotor, which is mounted on ball-and-roller bearings inside the needle casing. It is therefore the rotor which provides the vibration, as will be seen from the illustration.

The "Johnson" vibrator will be found equally suitable for reinforced-concrete work or for mass concrete, such as road slabs, etc., merely by changing the size of needle as

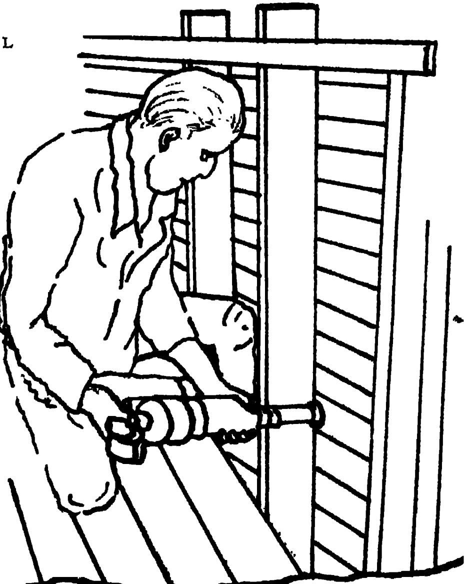


FIG. 9.—MECHANICAL HAMMER

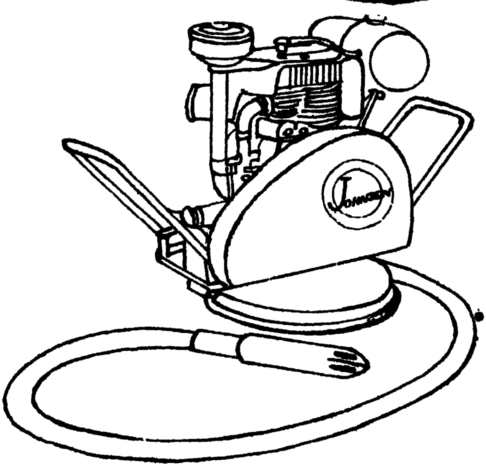


FIG. 10.—JOHNSON IMMERSION TYPE VIBRATOR (MODEL III)

(Reproduced by courtesy of C. H. Johnson (Machinery), Ltd.)

desired ; the smaller-diameter types are best suited for operation between reinforcements in walls, etc.

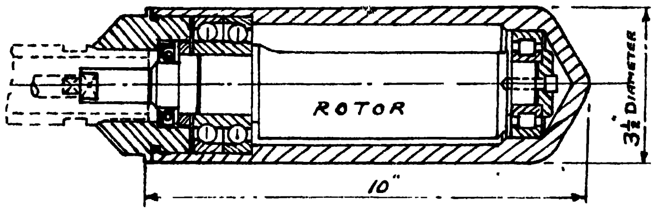


FIG. 10a.—3½-IN.-DIAMETER NEEDLE

Mechanical Mixing Machines (or " Mixers ")

These vary considerably in design, size, and type, according to the different manufacturers.

The sizes of batch-mixers are designated by their capacity in cubic feet of MIXED concrete per batch, with a letter to indicate the type of mixer. British Standard Specification No. 1305 covers concrete mixers of the following types :—

> *Tilting Type.*—" A concrete mixer comprising a single compartment drum having one opening and rotating on an inclined axis."
>
> *Non-tilting Type.*—" A concrete mixer comprising a single compartment drum, having two openings and rotating on a horizontal axis."

Thus a mixer of size 5 T. has a mixed-batch capacity of 5 cu. ft. of concrete, and is of the tilting type. A 5 N.T. size indicates a mixer of the same capacity, but of the non-tilting type.

According to British Standard Specification No. 1305, mixers, when operating on the level, should be capable of holding and making a batch 10 per cent. in excess of the nominal capacity, and the loading-hopper 50 per cent. more than the nominal batch capacity.

Various mixers are shown in Figs. 11–35 inclusive.

A small tilting-drum-type mixer, made by Messrs. Frederick Parker, Ltd., and known as the " Mini-Giant ", is

shown in Fig. 11. This machine (equipped with rubber-tyred wheels) is suitable for towing by a private car, and is particularly suited for the small builder or for repair jobs in scattered areas. It has a capacity of 3/2 cu. ft., but a high mixing angle.

Although not recommended for obtaining the best results,

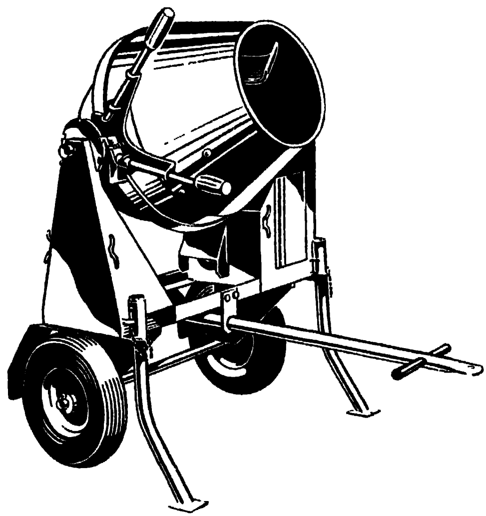


FIG. 11.—MINI-GIANT MIXER

(Reproduced by courtesy of Frederick Parker, Ltd.)

its drum will, in emergencies, take a batch at least 50 per cent. in excess of the given capacity.

The machine is operated by a 1-h.p. petrol engine, which, although entirely enclosed, is equipped with easily removable covers, thereby providing free access for repairs or adjustments. The complete machine weighs only 5½ cwt. and is 2 ft. 4 in. wide. It is very economical, and is not only suitable for builders and plasterers, but will also be found equally suitable for farmers, estate managers, and many other small users.

Another somewhat similar, but slightly larger machine is the "Little-Giant", made by the same manufacturers, and illustrated in Figs. 12 and 13. This is mounted on either a two- or four-wheeled chassis of steel- or rubber-tyred pattern. It is available in two sizes—7/5 cu. ft. and 5/3½ cu. ft.—and may be supplied driven by a petrol or paraffin

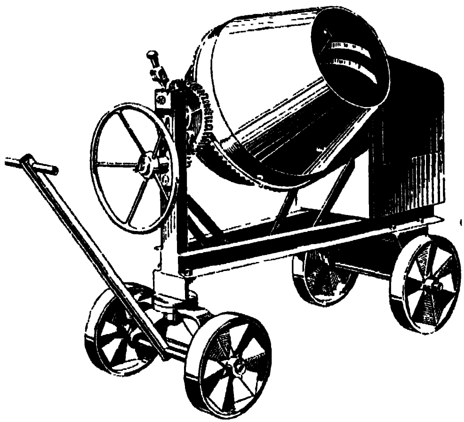


FIG. 12.—LITTLE GIANT MIXER
(Reproduced by courtesy of Frederick Parker, Ltd.)

engine, or an electric motor. The drum is equipped with double mixing-blades, and gives a high-speed uniform mix.

The machine may be supplied also as a manually driven unit, or for belt drive from an independent engine or tractor "power take-off".

A further small mixer—the "Winget" 2 T.—is shown in Fig. 14. This has a capacity of 3/2 cu. ft., and the drum is of the tilting type. It is mounted on a barrow-type tubular-steel chassis, equipped with two rubber tyres, and may be wheeled about the site or, since it weighs only 2 cwt. 3 qr. may be carried by two men. A telescopic tow-bar is provided, thus enabling it to be towed from place to place.

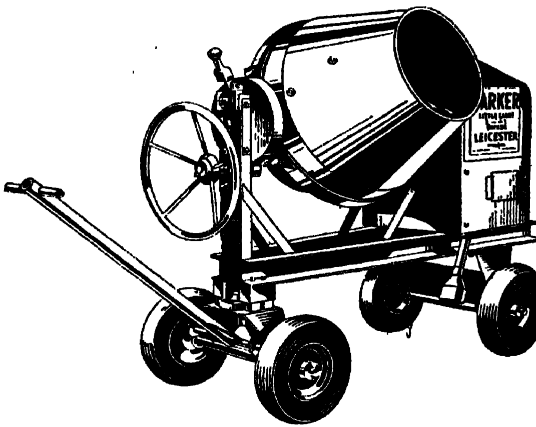


FIG. 13.—LITTLE GIANT MIXER (RUBBER TYRED)

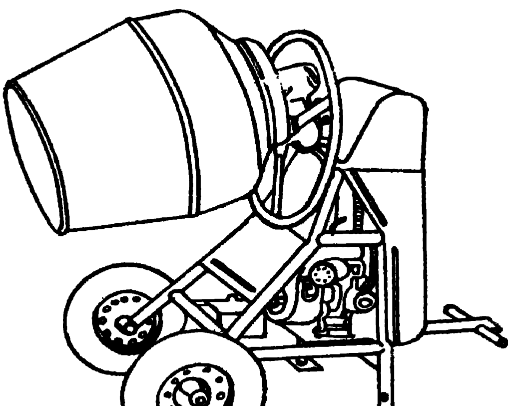


FIG. 14.—WINGET 2 T. MIXER
(Reproduced by Courtesy of Winget, Ltd.)

Since the machine is only 2 ft. $5\frac{1}{2}$ in. wide, it will pass through a doorway easily, thereby making it very suitable for small builders, etc. The power unit is either a 0·9-h.p. "Villiers" engine or a single-phase electric motor of $\frac{3}{4}$ h.p. with totally enclosed drive. As an alternative, this mixer can be mounted on an adapted frame and driven from a tractor power "take-off".

Among other small mixers is the "Tampkin", made by

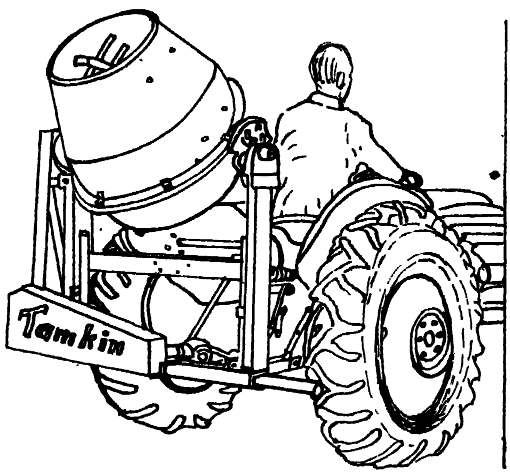


Fig. 15.—Tamkin $3\frac{1}{2}$ T. Tractor Mounted Concrete Mixer

Tampkin Bros. & Co., Ltd., which has a capacity of $5/3\frac{1}{2}$ cu. ft. and is usually supplied for attaching to, and being driven from, any of the well-known makes of tractors (see Fig. 15).

Another $5/3\frac{1}{2}$-cu.-ft.-capacity model is the "Benford" C.R.P.D., made by Benford, Ltd. It is mounted on a four-wheeled chassis frame and is driven by a small Diesel gas-oil engine—which the makers claim is very economical in fuel costs, as well as in maintenance (see Fig. 16).

These two last-mentioned mixers, in addition to their

appeal to small builders, will be found equally suitable for farmers and estate managers for repair works, etc.

A further type is the "Winget" 3½ T., which is mounted on a four-wheeled chassis and may be driven by either a petrol or diesel-oil engine (see Fig. 17). This machine has a hand-fed tilting drum, and when equipped with a diesel-oil engine weighs 14½ cwt. complete.

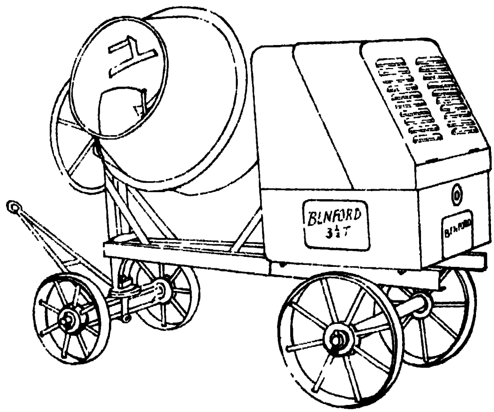


FIG. 16.—BENFORD 3½ T. MIXER (DIESEL ENGINE DRIVEN)

It may also be supplied mounted on a two-wheeled, rubber-tyred trailer, suitable for towing behind a car.

The "Rapier" 3½ T. concrete mixer—made by Ransomes & Rapier, Ltd.—is shown in Fig. 18. It is equipped with a patent tilting-type drum, with lattice-type self-cleaning blades, and is driven by a 1½-h.p. Lister petrol engine, through a Renold enclosed chain drive, or, as an alternative, it can be driven by a flame-proof electric drive.

The machine can be supplied mounted on either a chassis having four pressed-steel wheels or a chassis having four rubber-tyred road wheels, complete with telescopic handle (or draw-bar).

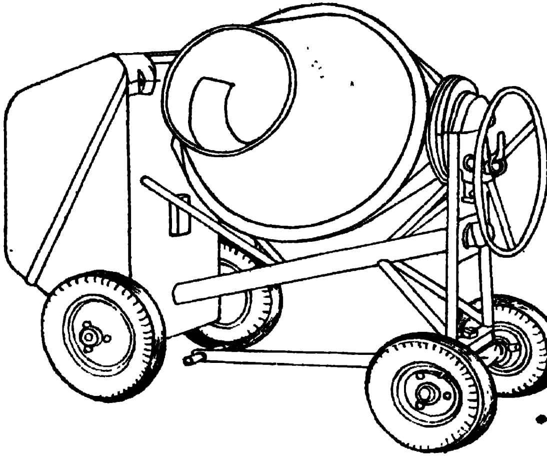


FIG. 17.—WINGET 3½ T. MIXER
(Reproduced by courtesy of Winget, Ltd.)

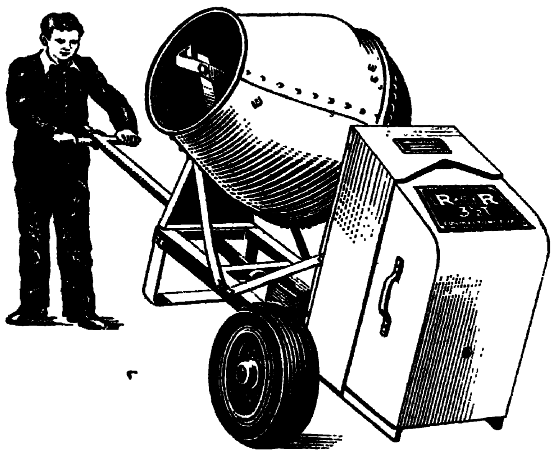


FIG. 18.—RAPIER 3½ T. MIXER
(Reproduced by courtesy of Ransomes & Rapier, Ltd.)

Another popular size is the "Rapier" 5 T., shown in Fig. 19.

This machine is equipped with a power-operated loading hopper for feeding the mixing-drum, which is of the tilting type. It is also supplied with automatic regulated water supply from an overhead tank, the whole plant being

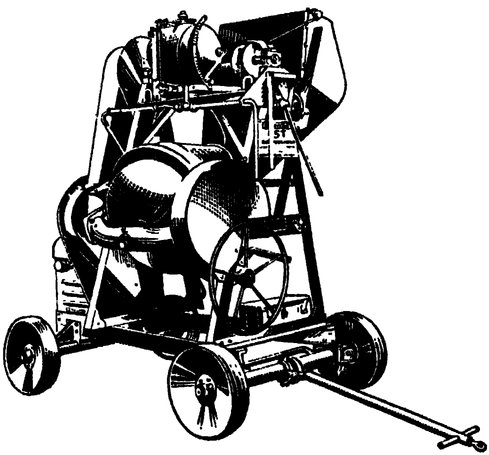


FIG. 19.—RAPIER 5 T. MIXER

(Reproduced by courtesy of Ransomes & Rapier, Ltd.)

mounted on a robust steel structure, fitted with four road-wheels and draw-bar.

This model is also made in a larger size, known as a 7 T. type. Both models may be driven by petrol, paraffin, or diesel engines, or by electric motor.

Another small mixer of the mobile tilting-drum type is the "Acrow" 3½ T., shown in Fig. 20, and made by Acrow (Engineers), Ltd. This machine has a double cone-shaped drum, one end being used for feeding and the other for discharge. The mixing-blades fitted to both cones provide

an " end-to-centre " action—which is claimed to give very efficient mixing.

The tilting operation for discharging is performed by a lever, which can be mounted on either side of the drum. The power unit may be either a 2-h.p. petrol engine or electric motor.

A spring-mounted axle carries the framework of this

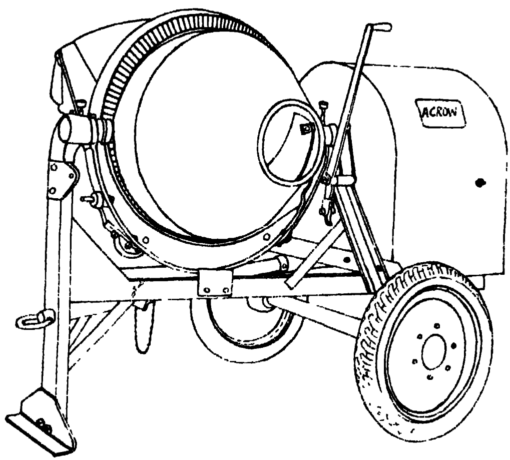


FIG. 20.—ACROW 3½ T. MOBILE MIXER
(Reproduced by Courtesy of Acrow (Engineers), Ltd.)

machine, and is fitted with two rubber tyres and telescopic draw-bar for towing by car or truck.

Fig. 21 shows a well-known 3½-T.-type mixer, made by Stothert & Pitt, Ltd. It is of the towing type, and is ideal as a general-purpose machine for builders, contractors, or farmers. The machine—which conforms to British Standard Specification No. 1305 of 1946—is of substantial construction.

The mixing-drum is of orthodox pattern and is mounted on a steel framework. It is driven by either a " Lister "

1½-h.p. water-cooled petrol engine or a 1½-h.p. "Petter" air-cooled petrol engine, but may also be supplied with either petrol–paraffin engine or electric motor. The standard drive is by Renold and Coventry chain equipped with automatic tensioning device. An all-steel frame is provided, which may be mounted on either four steel (or

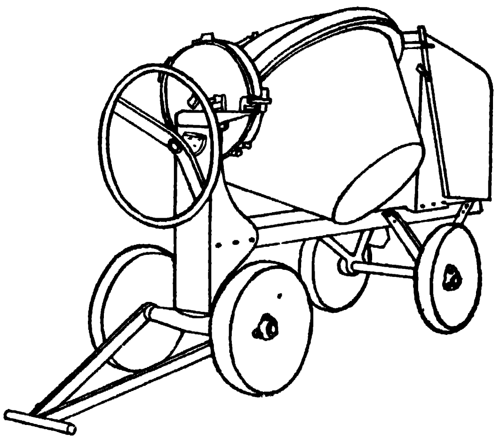


FIG. 21.—3½ T. MIXER

(Reproduced by courtesy of Stothert & Pitt, Ltd.)

pneumatic-tyred) wheels or a single axle with either steel or rubber-tyred wheels.

The approximate total weight of the machine is 10½ cwt. for the two-wheeled type.

The multi-plane four-bladed mixing-drum ensures consistent mixing of all normal batches. Grease-gun type lubrication is provided throughout.

The "Liner" Cadet, shown in Fig. 22, is another well-known mixer, and has a capacity of 3 cu. ft. (unmixed) for making 2 cu. ft. of finished concrete plus 10 per cent. It is a sturdy little machine—powered by a 1-h.p., four-

stroke, air-cooled petrol engine—which is economical and very suitable for small jobs.

The drum and engine unit are mounted on a steel frame which can be fitted with either steel or pneumatic-tyred wheels.

The "Cadet" mixes concrete, mortar, plaster, etc., with equal efficiency and has a total net weight of only $4\frac{1}{2}$ cwt.

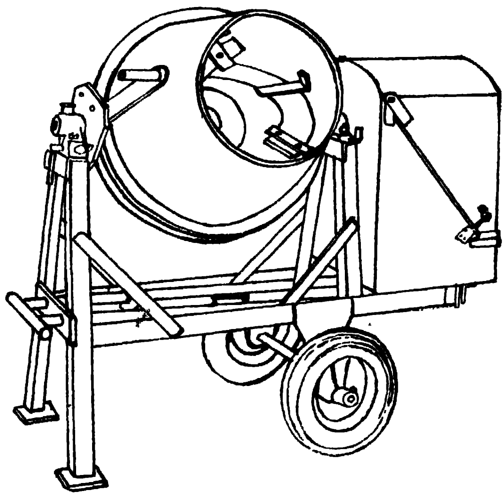


FIG. 22.—LINER CADET MIXER (SIZE 2 T.)
(Reproduced by courtesy of Liner Concrete Machinery Co., Ltd.)

It has a width of 27 in., thereby permitting its transit in narrow passages in buildings, etc.

Another machine made by the same firm is the "Trailex" $3\frac{1}{2}$ T., which is illustrated in Fig. 23. It is designed especially for towing behind a lorry or car, and is so arranged that the drum discharges direct into a wheel-barrow.

Further special features are: large-diameter sprung pneumatic-tyred wheels; strongly constructed frame and

low centre of gravity for high-speed towing; towbar with over-run brakes, adjustable jacks, and unobstructed discharge into wheelbarrow. The machine may be equipped with a petrol or paraffin engine or an electric motor.

Considering now machines of slightly larger type, and those equipped with power-operated loading hoppers and automatic water supplies; many of these exist and are used for larger jobs.

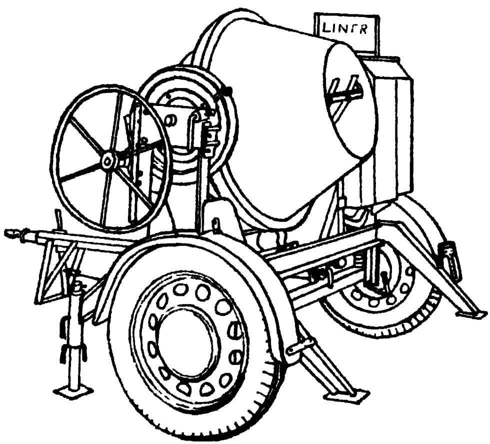


FIG. 23.—LINER TRAILEX JUNIOR MIXER (SIZE 3½ T.)
(Reproduced by courtesy of Liner Concrete Machinery Co., Ltd.)

Fig. 24 depicts a "Winget" 5 T./H.-type mixer, with its loading hopper in the discharge position—feeding the drum. Its tilting-type mixing-drum is of cast Meehanite metal, which resists wear very well. The whole machine is of robust construction, and has a self-discharging, tilting-pattern, water-cistern supply unit, which operates automatically when the mixing-drum is in position.

Power for operating the drum and for hoisting the loading hopper is supplied by one unit, which can be either a petrol

or diesel engine. The whole machine weighs approximately $1\frac{1}{2}$ tons.

A slightly larger version of this machine is also made in the 7 T./H. size.

The Parker "Speedia" tilting-drum mixer (Fig. 25) is

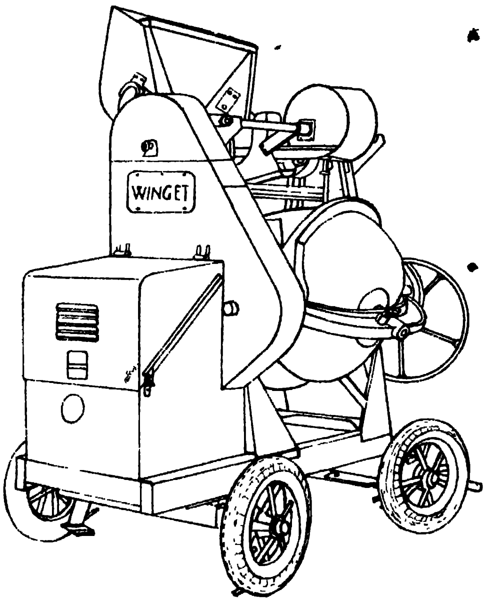


FIG. 24.—WINGET 5 T./H. MIXER
(Reproduced by courtesy of Winget, Ltd.)

another of the power-operated loading-hopper pattern. It is made in two sizes—10/7 and 7/5—and is of robust construction, as depicted in the illustration.

Its special features include automatic loading operation and a self-measuring water-tank, and it is available with either four steel or pneumatic-tyred wheels, and with choice of petrol, paraffin, diesel engine, or electric motor.

So far all the concrete mixing-machines considered have

been equipped with tilting-type drums for discharging into wheelbarrows or tipping bogies, etc.

Consideration will now be given to those machines—mostly of larger type—which have loading hoppers that discharge into NON-tilting mixing-drums. In the case of the latter, the drums merely rotate, and the efficient mixing is performed by " lifters " or " stirrers " inside the drum, after

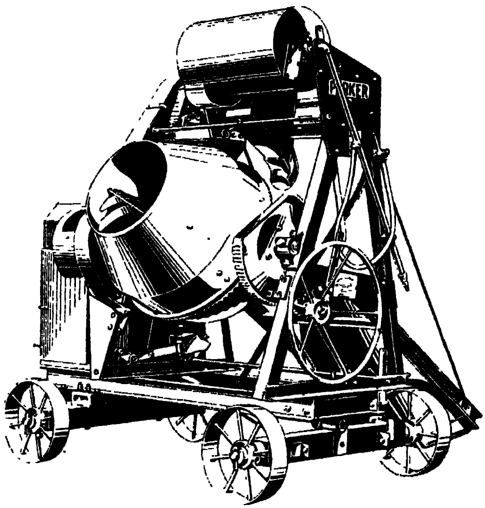


FIG. 25.—SPEEDIA TILTING DRUM MIXER

(Reproduced by courtesy of Frederick Parker, Ltd.)

which the contents are discharged by a chute from the drum.

Fig. 26 shows the " Super Victoria " type made by Messrs. Stother & Pitt, Ltd. It is made in 5 N.T., 7 N.T., and 10 N.T. sizes, and conforms to British Standard Specification No. 1305, of 1946 (concrete mixers).

These machines, which are of rigid construction throughout, are equipped with very efficient mixer-drums. The loading is effected by a tilting-type hopper, operated by

steel cables over a winding barrel, and the unit is equipped with a brake and clutch for manual operation by one man.

A water-pump, driven from the engine-shaft, pumps water (from the supply source) to a tank on the top of the machine, and its discharge is operated on the syphon principle. A gauge-glass indicator is fitted, whereby the operator can see

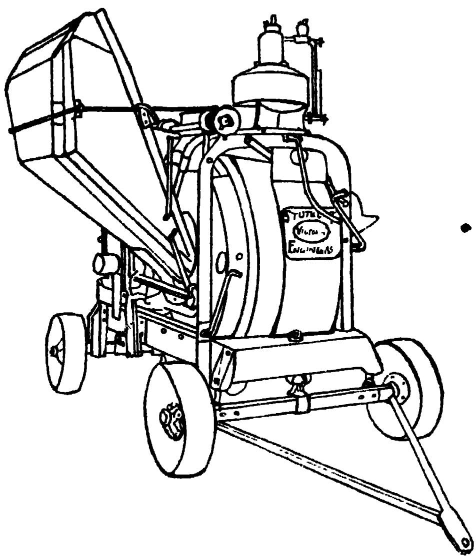


FIG. 26.—SUPER VICTORIA MIXER
(Reproduced by courtesy of Stothert & Pitt, Ltd.)

when the tank is full, and is calibrated to serve as a visible check on the quantity of water discharged. By this means a close regulation of the water supplied to the drum can be maintained.

If the source of water supply on the site is by pressure, the pump can be dispensed with and the supply connected direct to the tank, which is fitted with an automatic cut-off valve, which operates when the tank is full.

The discharge of mixed concrete is effected by means of a swing-type chute, pivoted above the drum discharge opening. When inserted into the drum, the chute receives the mixed concrete from the drum-blades as they rotate, and the chute angle, being very steep, ensures a ready flow of concrete to a waiting receptacle. The whole machine is mounted on a strong frame having four wheels, which can be either of plain steel or rubber-tyred pattern. Power units of either petrol, diesel, or compressed-air engine may be supplied, or, as an alternative, an electric motor may be used.

Another well-known and popular non-tilting drum-type mixer is the " Liner " 10/7 size, shown in Fig. 27, which can also be supplied in 7 N.T. size. Both types are substantially constructed, and mounted on four-wheeled-type chassis, having either rubber-tyred or plain steel wheels.

A special feature of this machine is the reduction in noise during its operation, since the drum is mounted on, and driven by four rubber-tyred rollers, thereby eliminating any gear-ring or chain-ring round the drum.

Both sizes of machine conform with British Standard Specification No. 1305, of 1946, mentioned earlier.

Another special feature of this type of mixer is the oval-section discharge chute with a 40° discharge angle. It is self-locking in discharge and mixing positions.

The power loading hopper is operated by steel wire cables, and a friction clutch and brake are provided for the mechanism.

The water-tank can be set to provide any given quantity required, by means of a visible indicator.

Either machine can be driven by petrol or diesel engine.

Fig. 28 shows a further type of NON-tilting drum mixer, made by F. Parker, Ltd. This model can be supplied in two sizes: 10/7 or 14/10-cu. ft. batch capacities. The smaller size can be equipped with two pneumatic-tyred wheels or four plain steel wheels, and the larger size with four steel or pneumatic-tyred wheels.

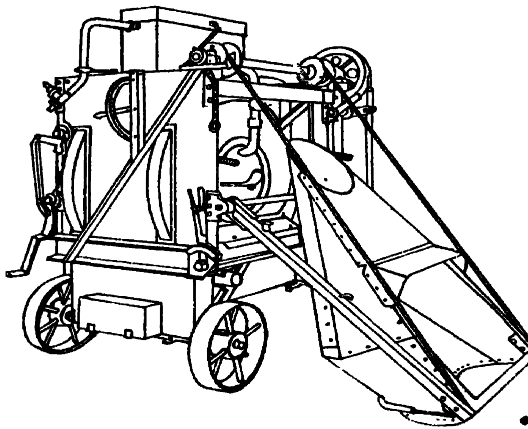


FIG. 27.—LINER N.T. MIXER (10/7 SIZE)
(*Reproduced by courtesy of Liner Concrete Machinery Co., Ltd.*)

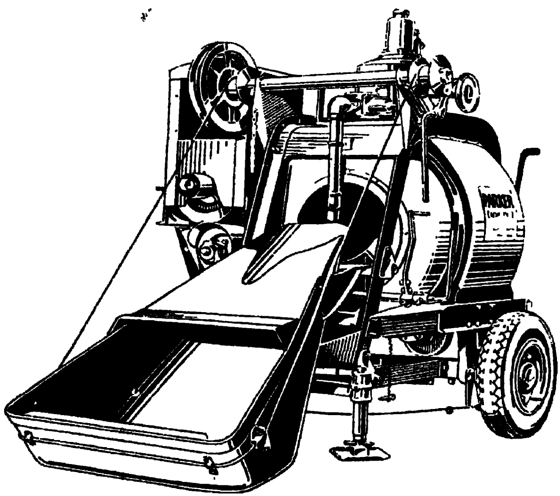


FIG. 28.—10/7 AND 14/10 N.T. MIXER
(*Reproduced by courtesy of Frederick Parker, Ltd.*)

In both sizes of machine the loading, mixing, and discharging are synchronized to ensure the fastest possible cycle of operations. These machines are of robust construction throughout. In both cases the loading hopper is operated by steel wire cables over winding barrels, and the machines are fitted with friction clutch and brake.

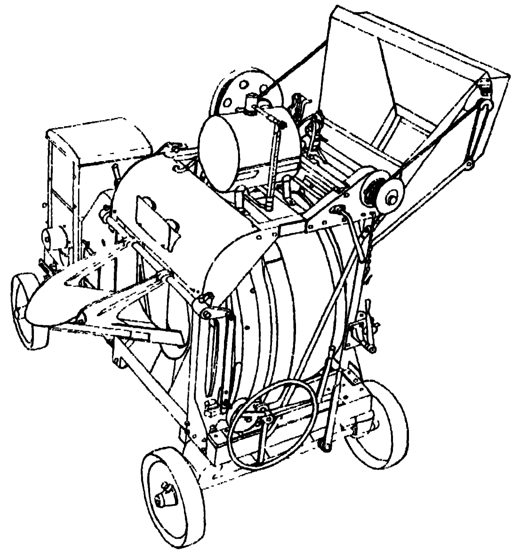


FIG. 29.—WINGET N.T. MIXER (SIZES 10/7, 14/10, AND 21/14)
(Reproduced by courtesy of Winget, Ltd.)

In Fig. 29 another type of conventional NON-tilting drum-mixer is shown. The chief features claimed for this machine—which is made in the four sizes indicated in the illustration—are : low back, high discharge angle, accurate water control, drum design for accurate handling of modern mixes, hand-operated hopper shaker, to ensure complete discharge without sticking or " caking ", and ball-and-roller bearings for long service.

These machines can be supplied with either plain steel-tyred or pneumatic-tyred wheels. They are of strong construction throughout, and "Meehanite" metal, which gives great strength and durability in service, is used in place of ordinary grey cast iron.

A further interesting and modern mixer is the "Winget" H.T.H. type (Fig. 30), which, although of the tilting-drum type, has its power-operated feed-hopper manipulated by a hydraulic ram, thereby eliminating the use of steel wire cables. It is equipped also with a weigh-batching mechanism—which is simple, easy to use, and can be dispensed with when desired.

Accuracy of water control is another feature of this machine, and is automatic in its action. A high discharge angle of 65° is achieved by the hydraulic tipping device for the loading hopper.

Alternative engine units are Lister F.R./1 diesel, Petter A.V.2 diesel, Petter P.A.2 petrol engine, or standard electric motor.

Fig. 31 shows one of the largest mobile mixers made—the Stothert & Pitt's 56 N.T. "Super Victoria". This is of massive construction throughout, and its loading hopper is of sufficient size to accommodate a 3-cu.-yd.-capacity "dumper" wagon to enter and discharge its load.

It is driven by a 38-B.H.P. four-cylinder diesel engine, or equivalent electric motor, and enclosed in a sheet-steel cabin.

The mixer is fed by an 84-cu.-ft. power-loader hopper, which is hoisted in inclined guideways through the medium of an oil-immersed coil clutch, on six falls of steel wire rope, equal loading on each fall being preserved by special adjusting screws.

Foolproof clutch knock-out gear, grease-packed, ensures automatic clutch disengagement at the maximum loader discharge angle, and independent brake-gear smoothly controls the lowering of the loader.

All controls are grouped at operating platform level, and

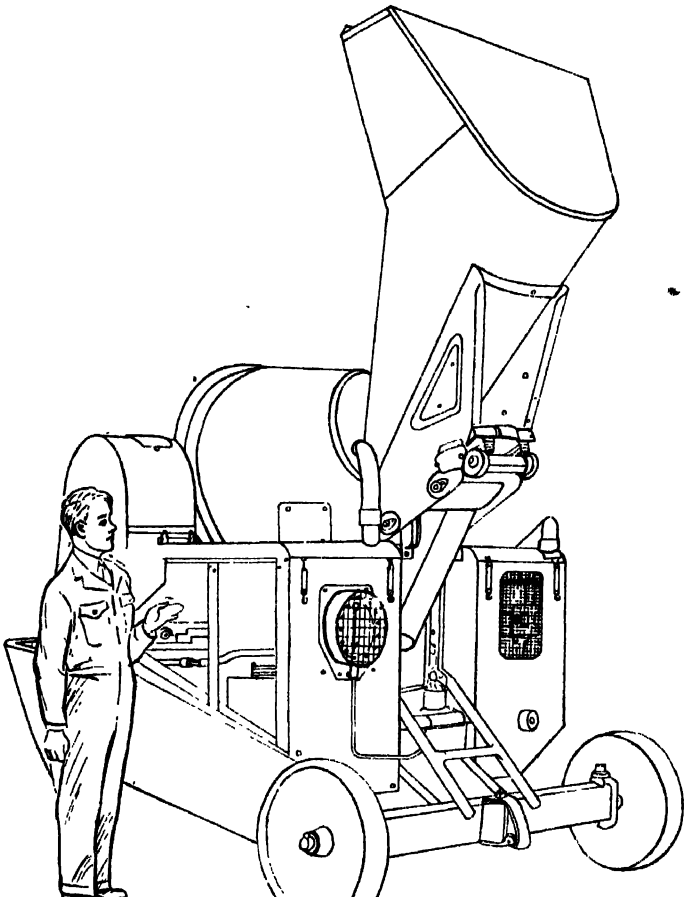


FIG. 30.—WINGET H.T.H. MIXER
(Reproduced by courtesy of Winget, Ltd.)

control levers are poised for easy manual operation. The discharge spout is hand-wheel operated, and locks automatically in both the " in " and the " out " positions.

All lubrication points are connected by fixed or flexible

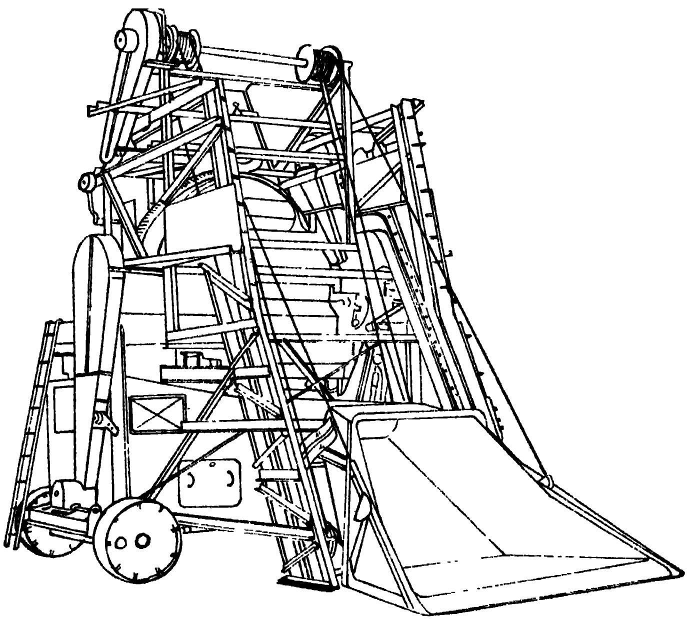


FIG. 31.—SUPER VICTORIA (SIZE 56 N.T.)
(Reproduced by courtesy of Stothert & Pitt Ltd.)

pipe-lines to a manually operated grease-pump, which is conveniently mounted on the main operating platform.

The approximate weight of the machine (on skids) is $7\frac{3}{4}$ tons, with road truck and loader frame (high discharge) $9\frac{1}{2}$ tons extra.

The mixed-batch capacity of this machine is 56 cu. ft.

The whole unit complies with British Standard Specification No. 1305 of 1946.

Batch-Mixing Plant

On large concreting jobs it is frequently advisable and more economical to instal one central batch-mixing plant instead of having several small mixers spaced about the site.

A large batch-mixing plant manufactured by Stothert & Pitt, Ltd., is shown in Fig. 32. This is constructed on the unit principle for ease of erection and transportation. It incorporates a 1-cu.-yd. concrete mixer and a three- or four-compartment hopper with a total capacity of 40 cu. yds. Extensions are available to increase the storage to 60 cu. yds.

The complete batching unit is mounted on four braced structural columns or piers, all of which are interchangeable to facilitate erection.

When assembled, the batcher can be operated by one man—from the second stage or platform, where all controls are centralized. The mixer is mounted on the first stage (as shown), and on the second stage are placed the weighing unit and bottom of the main storage hopper. The latter is installed on the third stage. A totally enclosed bucket-type elevator is installed for supplying the cement to the cement hopper. Power for the cement elevator and mixer can be by either diesel engine or electric motor. Materials are fed by crane direct into the compartment storage hopper; and the same crane can be used for erecting (or dismantling) the whole batcher unit. Each of the three or four compartments has an outlet fitted with a helmet-type door, lever operated from the control platform, and for delivery into the weighing hopper.

Cement is stored in a separate hopper of 30 cu. ft. capacity, and feeds by means of a helmet door into the weighing hopper; this weighing hopper feeds direct into the batch hopper of the mixer.

The mixer used is a Super Victoria 28 size. The weigher is fitted with a dial graduated in 10 lb. and reads up to 4,400 lb. A vertical water-tank of syphon type auto-

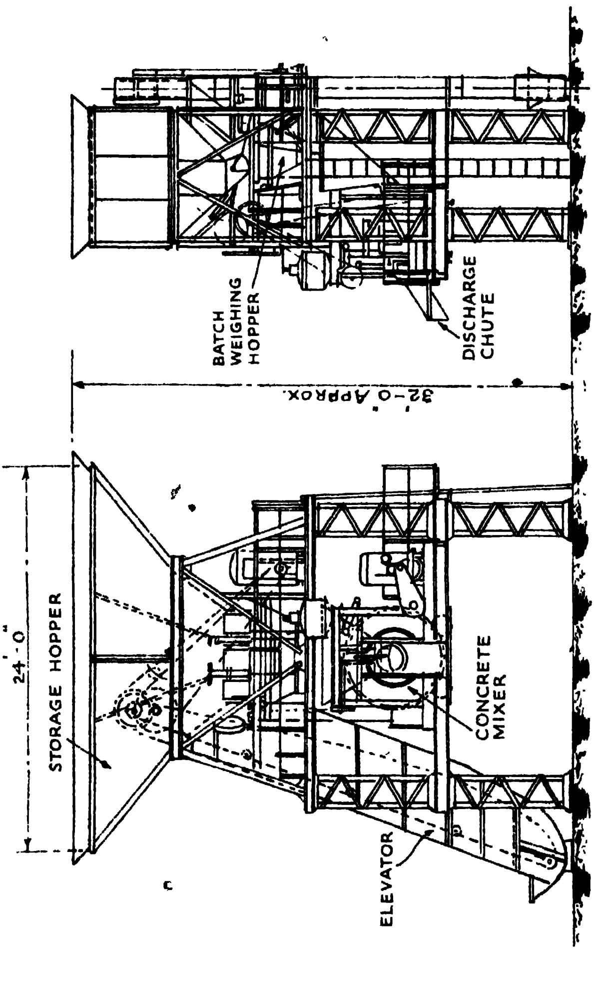


FIG. 32.—BATCH-MIXING PLANT

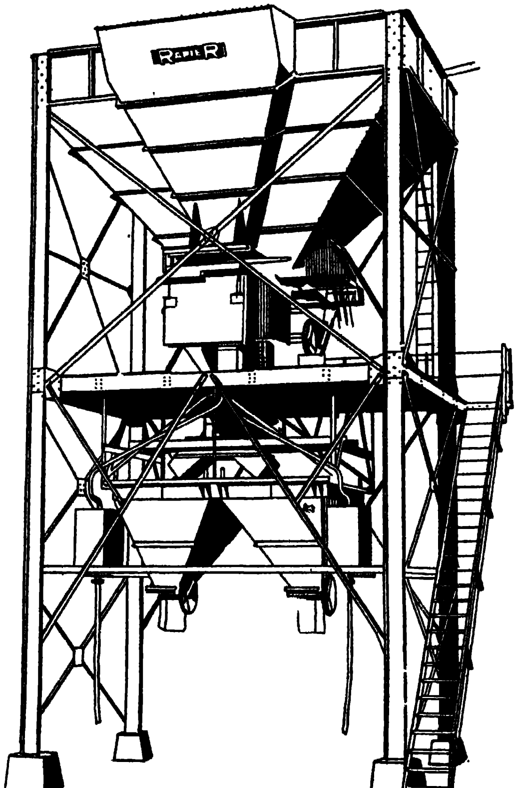


FIG. 33.—BATCH-MIXING PLANT
(*Reproduced by courtesy of Ransomes & Rapier, Ltd.*)

matically delivers a predetermined quantity of water dependent on the adjustment of its syphon tubes. A visual scale enables an exact setting of the required water discharge to be made; a lengthened scale is calibrated to show the amount of water that will be discharged at any particular setting of the pointer. The pointer is raised or

lowered by an operating handle mounted at the central control position. The handle is geared up with the spindle which raises or lowers the syphon tube in the tank.

The whole plant can be dismantled and conveyed from place to place by lorry and trailer.

A further batch-mixing plant, made by Messrs. Ransomes & Rapier, Ltd., is shown in Fig. 33.

The raw materials for this plant are fed by a crane to the overhead storage hoppers. These plants have many unique features for promoting sales of truck-mixed and centrally batched concrete, or batched aggregate, and will be found of especial interest for large construction jobs.

Note.—In addition to the various mixer machines described and illustrated, numerous types and sizes are made by other manufacturers, but most of the types described are those of which the author has had experience and with which he is therefore familiar.

Mixing Time

A mixing time of not less than two minutes after all materials (including water) have entered the mixing-drum is generally recognized as a satisfactory period for mixers up to 1 cu. yd. capacity. A time slightly in excess of this should be allowed for mixers exceeding that capacity.

Concrete mixers should always be operated at the speed recommended by the manufacturers.

Output of Mixers

The machines used should invariably be of a capacity sufficient to produce the required volume of concrete per hour without reducing the mixing time per batch.

Where a larger output is required, it should be obtained either by using a larger machine or by employing additional mixers, and *not* by speeding up the running or overloading the plant.

Fig. 34 gives a table of the output of the more common

sizes of mixer machines for different mixes using a 1-cwt. bag of cement as the basis for the batch of materials.

FIG. 34

Approximate Output of Mixers in Cubic Yards Per Hour for Whole 1 Cwt. Cement Batches of Materials, Allowing a Period of Three Minutes for Loading, Mixing, and Discharging

Nominal mix by volume.	Proportions per cwt. of cement (cu. ft).	Yield of concrete per cwt. of cement (cu. ft).	Output in cu. yds. per hour. Size of mixer (cu. ft.).				
			$3\frac{1}{2}$.	5.	7.	10.	14.
1 : 1 : 2	$1\frac{1}{4} : 2\frac{1}{2}$	3·4	$2\frac{1}{2}$	$2\frac{1}{2}$	5	7	10
1 : $1\frac{1}{2}$: 3	$1\frac{7}{8} : 3\frac{3}{4}$	4·6	—	$3\frac{1}{2}$	$3\frac{1}{2}$	7	$10\frac{1}{2}$
1 : 2 : 4	$2\frac{1}{2} : 5$	5·75	—	-	$4\frac{1}{4}$	$4\frac{1}{4}$	$8\frac{1}{2}$

Where the operating period is shorter or longer than three minutes, the output will be increased or decreased proportionally.

Operation of Mixers

The majority of large mixer machines are equipped with power-operated loading hoppers, thereby enabling the aggregate and cement to be fed simultaneously into the mixing-drum. The water should be added to the drum at the same time as the other materials, to ensure even distribution of the mixing water over the dry materials.

Many machines have cisterns attached which can be regulated to supply a measured quantity of water as required for any particular water–cement ratio previously decided on. Smaller machines are often not equipped with separate water-measuring devices, and thus rely on the operator adding the requisite amount, which is usually supplied from a measured quantity in a bucket or can.

When the concrete is mixed, the complete contents of the drum should be discharged at one operation into a hopper,

container, or bogie. Mixing time is lost and risk of segregation occurs if a batch is discharged into a number of separate barrows or bogie-wagons.

At the start of the day the first batch or two of the concrete may be harsh or stony, owing to the mortar sticking to the inside of the drum and around the drum blades (or arms). The proportion of the coarse aggregate may therefore be reduced for the first mix or so. However, if on a large construction job, it will be better still, and advantageous, to arrange for the supply of the first mixes to be used for small odd jobs, such as drain work, or other jobs of minor importance as compared with the main construction.

After use, and at the end of each day's work, the mixer-drum should be thoroughly washed out and the blades well cleaned, otherwise the drum will soon become caked with hardened concrete, which, in addition to being very difficult to remove, also impairs the efficiency of the machine.

Moreover, the inside of the drum should be inspected regularly and any blades which are broken or badly worn should be replaced.

Mixer machines equipped with loading hoppers operated by steel wire cables and winding pulleys should be inspected regularly, with a view to ascertaining the condition of the cables. This is especially necessary for machines fitted with steel tubing around the hopper and through which the cables pass. It is absolutely imperative to ensure that the tubes do not become choked with cement and water which sets hard. In the event of the cable having to be replaced, it is very difficult to dislodge. (Some modern large mixers are now equipped with hydraulic gear instead of wire ropes for hoisting the hoppers.)

A regular daily supply of grease into the tubes and along the cables will often prevent choking occurring, and will also prolong the life of the cable.

In some cases, especially when using damp sand and aggregate, these tend to stick inside the loading hopper—even when hoisted fully to its discharge inclination.

Workmen in the concrete gang may then be tempted to strike the hopper with a spade or shovel, in an attempt to effect a complete discharge into the mixer drum. Such practice should be discouraged, and the hopper should be struck only with a suitable wood rod in order to cause the necessary vibration.

Note.—Workmen have been known to strike loading hoppers with a sledge-hammer or pick-axe head in order to completely empty them. Concrete mixers were never intended for such rough usage, and will give efficient service if properly maintained and used with care.

Some concrete mixers, however, are equipped with a special agitating device whereby when the hopper is in its maximum discharging position, it is automatically vibrated by an eccentric cam and lever in order to effect a complete discharge.

Inspection and regular maintenance are essential if loss of time due to a breakdown of the mixing plant is to be avoided. In many cases it often pays to have the machines thoroughly lubricated and their petrol engines refuelled etc., during all meal breaks, so as to minimize the occurrence of breakdowns during working hours.

By paying close attention to such matters, often in the course of re-fuelling, etc., a loose bolt or nut may be detected, which may cause a breakdown later if passed unnoticed.

Moreover, in cold or damp weather it is advisable to have a supply of warm water available in order to facilitate the starting of the mixer engines at the beginning of the day's work, since much valuable time can then be saved by avoiding difficulty in starting-up operations. In cold weather it is advisable to drain the mixer-engine radiators, in case of night frost developing after the day's work.

Ready-Mixed Concrete

Ready-mixed concrete may be supplied by truck or transit mixers, operating from a central batching plant. This is especially useful in urban areas and in those areas

where the site is restricted for storage conditions of aggregate, etc.

The dry materials are fed into the mixing drum, the water added, and mixing started when the mixer approaches the site. Alternatively, ready-mixed concrete from a central mixing plant may be transported direct to the site (if within reasonable distance) in a specially designed container which keeps the mixture agitated during its journey.

When this procedure is adopted, special care must be

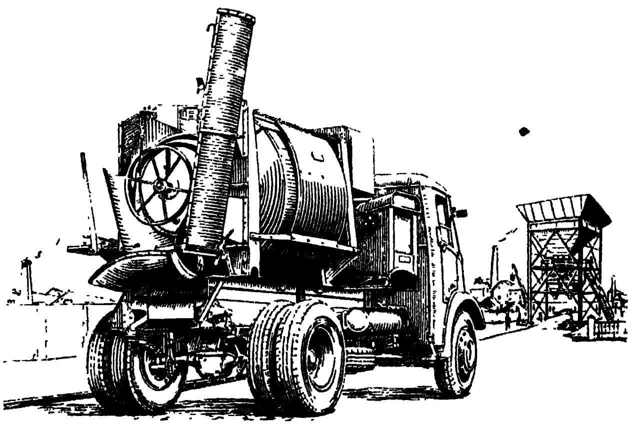


FIG. 35.—TRUCK MIXER
(Reproduced by courtesy of Ransomes & Rapier, Ltd.)

taken to ensure a regular delivery to the site to avoid stoppages which may adversely affect the finished work.

Several large contracting firms are now specializing in the manufacture and supply of ready-mixed concrete.

Fig. 35 shows a typical "truck-mixer" with its discharge chute hinged out of position for transit. On arrival at the site the chute is merely swung into the discharge position ready for delivering the mixed concrete. The large handwheel shown at the rear of the truck operates the mixer

discharge door, thereby regulating the flow of concrete down the chute. This type of truck mixer is very suitable for supplying mass concrete for large foundations below ground level, when the truck can draw up close and discharge direct.

These truck-mixers are made in 1½-, 2½-, and 4½-cu.-yd. sizes.

Placing and Transporting Concrete

The type of plant used for transporting the wet concrete from the mixer to the formwork (or shuttering) depends on the size of the job and the height above ground-level at which the concrete is to be placed. Wheelbarrows are commonly used for small jobs, but for large work lorries, "dumpers", and "jubilee" wagons (side-tipping skips) on narrow-gauge rail-track are employed for this purpose (see Figs. 36–40).

Sometimes, where large quantities of concrete are required, skips working in conjunction with cranes are used; this is often performed for building work high above ground. Hoists are sometimes employed for lifting the concrete to a hopper from which it may then be fed by a chute or barrows.

Where chutes are used, their slope and length, also the timing of operations, should be so arranged that an almost continuous flow of concrete is delivered at the discharge point, otherwise there is a risk of the larger aggregate separating from the fine material (i.e., segregation occurs). For this reason the concrete should be delivered into a hopper or bunker, where it can be thoroughly re-mixed, stirred, or agitated before being placed in the formwork.

Whichever method of transport is employed, care must be taken to guard against segregation, and no water must be added after the concrete has left the mixer.

At the end of the day's work all containers must be thoroughly washed out, and where chutes are employed and

are being cleaned, care should be taken to ensure that no waste water from washing enters the formwork.

Fig. 36 shows a typical steel barrow used for barrowing the concrete. It will be seen that the front part of the body has a flat slope to facilitate discharging operations. Modern barrows are now fitted with pneumatic-tyred wheels.

A "Cochrane" power-driven barrow is illustrated in

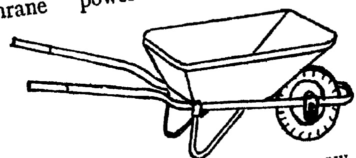


FIG. 36.—STEEL CONCRETE BARROW

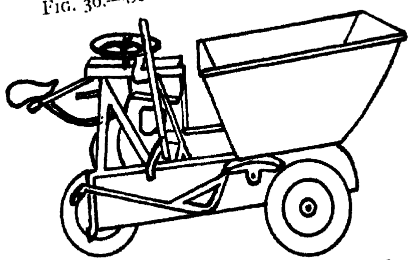


FIG. 37.—COCHRANE POWER BARROW

Fig. 37, and it will be noticed is equipped with a driver's seat from which all controls are manipulated.

A further type of power-barrow—the Winget "Mechanical Moke"—is shown in Fig. 38, but this is controlled by the driver walking alongside; hence the large-type steering-wheel, which can be operated from either side or from the rear.

This machine has an easily detachable skip body which can be quickly lifted off and replaced by a flat timber platform on which sacks of cement or other building materials can be transported.

Fig. 39 depicts a typical steel side-tipping wagon—commonly known as a "Jubilee" wagon. By releasing a catch at either end of the chassis the wagon can be tipped to discharge to either side.

These wagons are intended for use on narrow-gauge

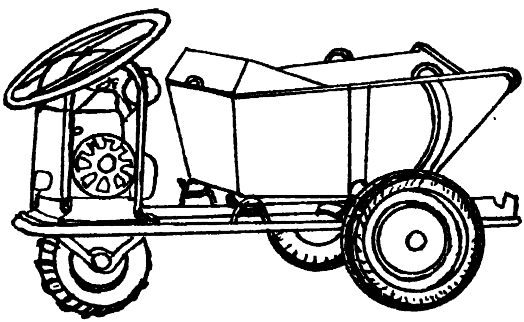


FIG. 38.—WINGET POWER BARROW, OR "MECHANICAL MOKE"

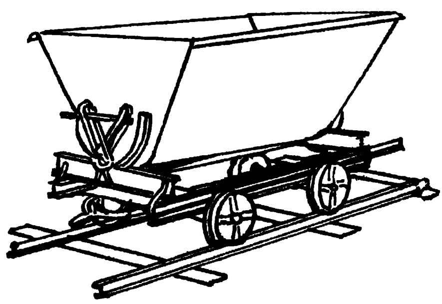


FIG. 39.—SIDE TIPPING WAGON

rail-track, and are available for 18-, 20-, 24-, 30-, 36-, and 42-in. gauge tracks. They can now be obtained mounted on pneumatic tyres for operating on firm ground.

Side-tipping wagons are made in a variety of sizes, which range from a capacity of 10 cu. ft. up to several cubic yards.

The smaller sizes can be pushed along manually, and can

be coupled together to form a small train; the larger sizes, when coupled to form a train, are usually hauled by a small power-operated engine, especially when the haulage distance is great. In addition to being used for carrying concrete,

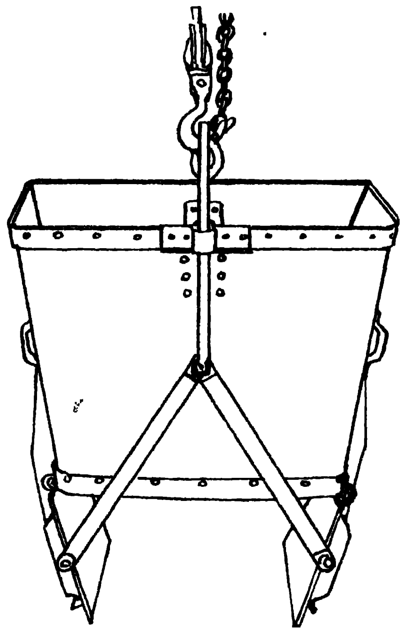


FIG. 40.—CRANE SKIP

these wagons are employed extensively for conveying soil during excavation and for similar purposes.

A typical—bottom-opening pattern—skip, such as is employed in conjunction with a crane, is shown in Fig. 40.

Pumped Concrete

On some jobs, often for foundations over large areas, mass concrete may be pumped through a pipeline, extending from the mixer to the discharge point. For this purpose a single-

acting force-pump with cylinder, valves, and valve lining made of special abrasion-resisting alloy is used.

The concrete from the mixer is discharged into the pump-receiving hopper, thence through the pipeline to the delivery point.

The pipeline is usually from 4 to 8 in. in diameter, and is composed of lengths or sections having special quick-release type couplings, so that lengths can be made up to suit the area over which it is desired to discharge. Moreover, some types have semi-flexible couplings whereby the pipeline can be deflected over the area of discharge, thus saving time by not having to disconnect and connect up the various lengths so frequently.

It is advisable that the first batches of concrete pumped through the pipeline should contain a slightly reduced quantity of coarse aggregate.

At the end of each day's work it is absolutely imperative to clean thoroughly the pipeline by using a "go-devil" through it, and then swilling the pipe out with clean water (which must not be allowed to enter the work).

It will be realized that for pumped concrete a higher slump has to be used, for the concrete will clog in the piping if too stiff. Moreover, the coarse aggregate must be of relatively small size to travel conveniently in the pipeline.

These factors, therefore, somewhat limit the use of pumped concrete for some jobs. Furthermore, it is a messy process, since, due to the daily washing-out operations in the vicinity of the mixer, pump, and pipeline, the whole area can soon become a quagmire.

Incidentally, concrete can be pumped to a height of 100 ft. or for a horizontal distance of 1,000 ft. when, in using a 6-in. pipe, an output of approximately 20 cu. yd. per hour has been attained.

Placing of Concrete

It is essential that the concrete be placed in its final position before the cement reaches its initial set. Concrete

which has acquired its initial set should never be used. Most specifications usually require concrete to be placed within HALF AN HOUR of its being mixed, and once placed (and consolidated) it should not be disturbed.

Before placing starts, the shuttering should be finally inspected, also the reinforcements—if any—to ensure that no misplacement of either has occurred. If timber shuttering is used, all shavings, sawdust, etc., should be removed.

The concrete should be spread evenly, and well rammed into any corners or spaces in the formwork (or shuttering), and concreting should proceed without interruption between predetermined construction joints.

Consolidation

The importance of consolidation cannot be emphasized too strongly, since the whole object of consolidation is to obtain a maximum density. Incidentally, the strength of concrete can be reduced by as much as 30 per cent. merely by the presence of 5 per cent. voids due to poor consolidation.

The methods employed to effect maximum consolidation, together with the tools used—hand rammers, tampers, and vibrators—are considered in other chapters.

With mechanical vibrators a drier mix can be used, thereby obtaining a higher-strength concrete with the same amount of cement as used in other methods.

CHAPTER II

TESTS AND TESTING OF MATERIALS

Cement Tests

Chemical and fineness tests are continually made at the factory during all stages of manufacture, thereby ensuring that only high-class cement is produced for distribution to users. Most British manufacturers supply qualities far in excess of the requirements of the relative British Standard Specification.

It is therefore after delivery and during storage that cement is likely to deteriorate, hence the necessity of storing in a dry place.

Although cement is both weighed and packed into bags (or drums) by automatic machine, the variation is so small as to be negligible, and in all cases at least 1 full cwt. is supplied to each 1-cwt. sack. The user may therefore, with every confidence, take a 1-cwt. sack as a basis for the mix (instead of 1 cu. ft.) if more convenient. In this respect the author has frequently witnessed the accurate checking of many 6-ton consignments of which every sack has contained a full cwt. which in no case has been exceeded by more than a few ounces.

Tensile Strength

In addition to cement being tested for fineness and its chemical composition—tests are also carried out, usually when mixed with sand, to ascertain its tensile strength.

To enable this to be performed, briquettes are made in detachable moulds. The briquettes consist of a mixture of cement and sand in the proportion of 1 part, by weight, of cement to 3 parts of standard sand, prepared in the pre-

scribed manner as described in the British Standard Specification previously mentioned.

The shape and size of a briquette are given in Fig. 41.

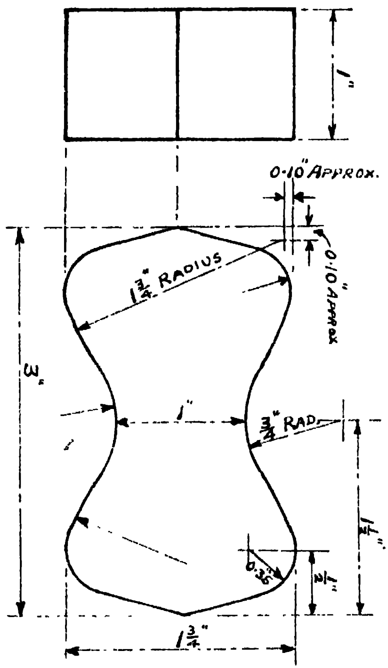


FIG. 41.—STANDARD BRIQUETTE

After being cast in the mould, the briquette should be kept in an atmosphere of at least 90 per cent. relative humidity for twenty-four hours. It should then be removed from the mould, immediately submerged in clean fresh water, and kept at a temperature of between 58° and 64° F., at which it should remain until ready for breaking.

Six briquettes for each period are tested for breaking strength in a special tensile testing machine, three days

(seventy-two hours) and seven days, respectively, after gauging.

The breaking strength is the average "*tensile*" breaking strength of the six briquettes for each period.

At three days this should be not less than 300 lb. per square inch of section, and at seven days not less than 375 lb. per square inch of section. Both figures are for cement of ordinary grade.

Soundness

In order to carry out tests for soundness, the "Le Chatelier" method is adopted.

The instrument used is a small cylinder of 30 mm.

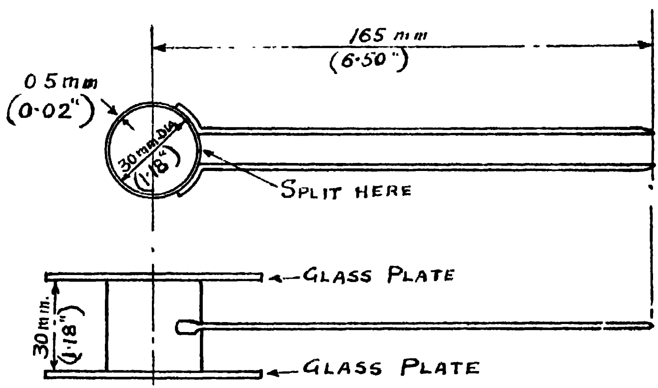


FIG. 42.—APPARATUS FOR LE CHATELIER TEST

internal diameter and of the same length. It is split along one side longitudinally, and has two arms attached to it. The cylinder thus forms a mould, and is complete with glass plates at both its ends (see Fig. 42).

In conducting the test, the mould (or cylinder) is placed on a sheet of glass and filled with cement paste of normal consistency, care being taken to keep the edges of the mould gently together whilst the filling is being performed.

The mould is then covered with another glass plate, on top of which a suitable weight is placed. The whole unit is then submerged in water at a temperature of 58–64° F., and kept there for twenty-four hours.

Next the distance separating the arm points is carefully measured.

The whole unit is again immersed in water and brought to boiling point in twenty-five to thirty minutes, and is then kept boiling for three hours. The mould is then removed from the water, allowed to cool, and the distance between the arm points again measured.

The difference between the two measurements represents the expansion of the cement—which should not exceed 10 mm.

Setting Time Test

This is performed by observing the penetration of a needle fitted to the "Vicat" test apparatus (see Fig. 43). A

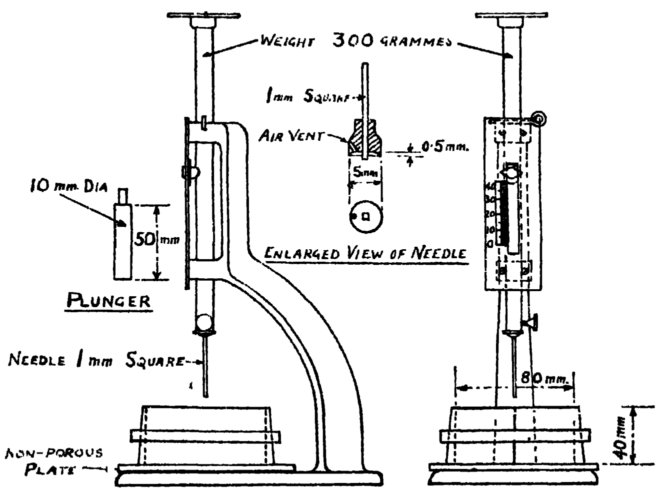


FIG. 43.—VICAT TEST APPARATUS

needle 1 mm. square and weighted to 300 gm., when lowered to the surface of the cement paste in the mould and quickly released, will pierce the block completely.

The operation is repeated until the needle will only reach a point some 5 mm. from the bottom of the mould. The period between the time when the water is added to the cement and the time when the needle ceases to penetrate the block completely is the initial setting time.

The needle used in finding the final setting time is 1 mm. square, but is fitted at the end with a metal attachment hollowed out so as to leave a circular cutting edge 5 mm. in diameter beyond which the needle projects 0·5 mm. The time adjudged to be the final setting time is that at which the needle makes an impression on the cement block but the circular cutting edge does not.

To comply with British Standard Specification No. 12, Portland cement must have an initial setting time of thirty minutes and a final setting time not exceeding ten hours.

SAND TESTING

Silt Tests

A rough test for the sand's cleanliness may be performed by placing a sample in a glass (jam) jar and adding about 50 per cent. of clean water.

The mixture should be shaken vigorously and then allowed to settle for twelve hours, a cover being placed on top of the jar to exclude dust or dirt.

The volume of silt (or scum) visible at the *surface of the sand* should then be noted. If the thickness of scum does not exceed one-tenth that of the sand, it may be considered suitable.

A more accurate test, however, may be carried out by procuring a 200-c.c. graduated measuring jar and filling it with sand up to the 100-c.c. mark. Clean water should then be added until the 150-c.c. mark is reached. The mixture should then be thoroughly shaken and the contents allowed to settle for one hour.

The amount of scum (or silt) should then be noted, and if it does not exceed 6 per cent. by volume, the sand may be considered satisfactory.

Test for Organic Impurities

A 12-oz. graduated prescription bottle should be filled to the 4½-oz. mark with a sample of the sand to be tested. A 3 per cent. solution of sodium hydroxide (NaOH) should then be added until the volume of sand and solution—after shaking—amounts to 7 oz.

The mixture should again be shaken vigorously and allowed to stand for twenty-four hours.

If, on inspection after this period, the clear liquid above the sand is found to be colourless or light yellow in colour, the sand will be satisfactory. If, however, the colour is found to be dark brown, the sand should not be used for concrete work.

"Bulking" Test

If the quantities of materials for any given mix are specified by volume, they usually apply to the materials when dry.

Coarse aggregate for a given volume differs only very slightly when wet or dry.

Sand, however, may vary considerably, since the "particles" of air and water adhere to those of the sand, thereby occupying a certain space.

If, therefore, a known quantity of damp sand is placed in a container, it wlll occupy more space than a similar volume of dry sand.

Sand as delivered to any site for concrete work—especially if dredged or washed—is damp, if not wet. This may lead to confusion in the quantities for the mix, unless account is taken of the moisture content already in the sand, especially when adding water for the water-cement ratio.

Some indication of this may be obtained as follows. Place a sample of the damp sand (as received) in a glass

container, partly filling it; lightly level it off and measure the height to its surface. Next add sufficient water to saturate it, and well stir the mixture; allow it to settle—say for six hours—and again measure the sand surface-level height.

The second dimension will be less than the first one measured, since the second dimension represents approximately the height of the volume of dry sand. The difference between the two dimensions represents the "bulking", and the additional percentage of sand should be added to the

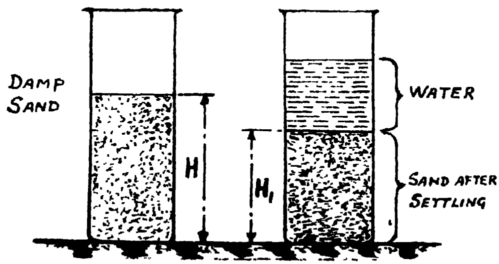


FIG. 44.—SAND BULKING TEST

given quantity for the mix so as to compensate for the loss due to bulking (see Fig. 44).

If H represents the height of wet sand (as received on site) and Hl the height after stirring and settling, then $\frac{H - Hl}{H} \times 100$ represents the percentage bulking.

Since different sands have different bulking properties, this should be considered in cases where the sand supply to any contract is switched from one supplier to another. It might transpire that supplies come from totally different localities, yet they may appear to all intents and purposes quite similar.

Fig. 45 gives a table showing the bulking of different types of sands, together with their percentage increase in

FIG. 45

Bulking of Different Types of Sands
(Sand Loosely Filled)

Percentage water content by weight of dry sand.	Percentage increase in volume.		
	Coarse.	Medium.	Fine.
2	14	29	37
4	23	37	45
6	27	40	47
8	28	40	49
10	26	39	49
12	24	38	48
14	22	36	47
16	19	33	45
18	15	28	42

(Reproduced by courtesy of The Cement & Concrete Association)

volume according to the percentage water content (by weight) of dry sand.

The following example shows the effect of the bulking of sand on the proportions of concrete. In a mix specified as 1 : 2 : 4 by volume (i.e., 1 cwt. of cement to $2\frac{1}{2}$ cu. ft. of dry sand, to 5 cu. ft. of gravel), if the sand is bulked by 25 per cent., the actual volume of damp sand required would be $2\frac{1}{2} \times 1\frac{1}{4} = 3\frac{1}{8}$ cu. ft.

To obtain the most accurate results, therefore, the bulking of the sand should be determined on each job.

Tests for Moisture Content

When a water-cement ratio is specified, an allowance must be made for water in the sand as delivered to the site. Moreover, the moisture content may vary somewhat in the consignments received throughout the day.

Approximate allowances are given for guidance as follows :—

Very wet sand—6/8 lb. of water per cubic foot of sand.

Moderately wet sand—about 4 lb. of water per cubic foot of sand.

Moist sand—about 2 lb. of water per cubic foot of sand.

When facilities are available, a known weight of damp sand (say 2 lb.) should be heated until it is dry (i.e., when the sand-grains attain a "free-running" condition), and the weight of water in the sample determined. This weight is usually expressed as a percentage of the dry weight.

The heat should not be too fierce, and the dried sand should not be weighed until it has cooled.

If facilities for heating the sample are not available, the moisture content may be determined by using an instrument called a pycnometer, which can be made from a 2-lb. preserving jar, to which is fitted a conical-shaped metal cap with a ¼-in.-diameter hole in the apex.

The method of use is described fully in Appendix F of British Standard Specification No. 882, to which the reader is referred for complete instructions.

Note.—Coarse aggregate which is very wet may contain 2 or 3 lb. of water per cubic foot.

The moisture content may, if desired, be found by drying a sample of known weight. A method of determining the absorption of coarse material is fully described in Appendix E of British Standard Specification No. 882.

The following example shows how to determine the amount of water to be added at the mixer :—

Materials per batch :	1 cwt. cement. 3½ cu. ft. damp sand. 4¾ cu. ft. coarse aggregate.

The equivalent volume of dry sand will be 2¾ cu. ft.

Water–cement ratio : 0·6 by weight.

Sand :	Weight 95 lb. per cu. ft. when dry. Moisture content 5 per cent.
Coarse aggregate	Weight 90 lb. per cu. ft. when dry. Moisture content 1 per cent.

Gross weight of water for 1-cwt. bag batch :	$0{\cdot}6 \times 112$ lb. $= 67{\cdot}2$ lb.
Weight of water in sand per batch :	$2{\cdot}75 \times 95 \times \frac{5}{100} = 13{\cdot}1$ lb.
Weight of water in coarse aggregate per batch :	$4{\cdot}75 \times 90 \times \frac{1}{100} = 4{\cdot}3$ lb.
Total weight of water in aggregates	$= 17{\cdot}4$ lb.

Water to be added at mixer : $67{\cdot}2 - 17{\cdot}4 = 49{\cdot}8$ lb. or 5 gallons.

To obtain concrete consistent in quality, it is therefore essential to maintain strict control of water at the mixer. Most of the larger mixers are equipped with a water-tank and gauge for measuring the quantity in gallons and/or in lb.

Some mixers are provided with a locking device for the discharge setting, which ensures that the quantity of mixing water can be altered only by the man in charge.

It is advisable to check the quantity of water actually entering the mixer-drum with the reading in the gauge or valve-setting, especially when starting a job or after moving the mixer, since if the mixer is set on an uneven base the siphon head may become displaced, and thereby affect the quantity of water being discharged.

Coarse Aggregate Tests

Cleanliness

Aggregates may be tested for cleanliness in a somewhat similar manner to those described for sand.

Hardness

For hardness, however, machines are now available whereby a sample aggregate is placed inside a steel container and given a specified number of blows from a steel weight, which produces chippings or dust. The quantity of dust can then be compared with that produced by different aggregate samples, each having received the same number of blows from the machine.

Absorption

Since some stone, rocks, etc., are porous, and therefore absorbent, tests may be performed as a means of comparison.

A sample may be thoroughly dried in an oven for a specified time.

The sample should then be weighed and recorded. It should next be immersed in clean water for twenty-four hours and again weighed. The difference in the two weights represents the amount of water absorbed.

Usually the harder the rocks, the less absorbent they are, thus rendering them suitable for making a hard, dense concrete.

The sizes of aggregates are determined by passing samples over B.S.S. sieves of the specified given size. The sieves used should comply with British Standard Specification No. 410.

For the manufacture of crushed, washed, and graded aggregates, large industrial plants are now in use which automatically perform these duties and deliver the various sized materials to overhead storage bins, from which lorries are loaded for conveying the aggregates to the concrete sites.

CONCRETE TESTS

Slump Test

In practice, the water content of concretes may be compared and controlled by making "slump tests".

This is performed by using a "slump cone", which is a truncated, cone-shaped mould with side handles and foot-rests for holding it when being filled (see Fig. 46).

In order to carry out a slump test, the procedure is as follows :—

The cone is placed on a non-absorbent level floor or surface, and filled in three stages of 4 in. each with wet concrete.

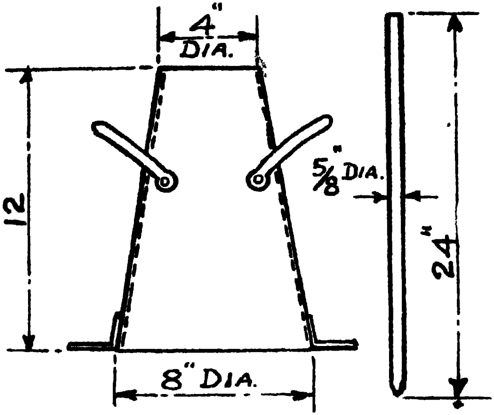


FIG. 46.—SLUMP CONE AND PUNNING ROD

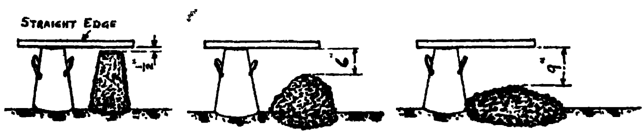


FIG. 47.—TYPICAL CONCRETE SLUMP TEST

FIG. 48

Typical Data for Slump Test as shown in Fig. 47

Slump test.	(*a*).	(*b*).	(*c*).
Mix	1 : 3 : 6	1 : 1½ : 3	1 : 2 : 4
Cement	Std. British	Same	Same
Slump	½"	6"	9"
Water content . .	6%	8½%	9%
Crushing strength at 28 days .	5,500 lb. per sq. inch	6820	4750

After depositing each 4 in., the concrete is consolidated by giving it twenty-five strokes with the "punning rod", being finally levelled off to the top of the mould.

The cone mould is then immediately lifted vertically, thereby drawing it off the concrete, and is placed vertically beside the latter, which will have settled or slumped, depending on the wetness of the mix.

The amount of settlement below the 12 in. height is measured in inches, and is known as the "slump" (Fig. 47).

By this means it is possible to work to a specified slump by carrying out tests at the beginning of the job, and also by frequently taking tests during the concreting. This ensures an approximate uniformity of water content.

Fig. 48 gives a typical table of mixes, slump, water content, and crushing strengths made twenty-eight days after concreting.

Fig. 49 gives typical slumps for use in various classes of work.

FIG. 49

Uses of Concrete of Different Degrees of Workability

Degree of workability.	Slump in inches.	Use for which concrete is suitable.
Very low	0 to 1	Vibrated concrete in roads or other large sections.
Low	1 to 2	Mass concrete foundations without vibration. Simple reinforced sections with vibration.
Medium	2 to 4	Normal reinforced work without vibration, and heavily reinforced sections with vibration.
High	4 to 7	Sections with congested reinforcement. Not normally suitable for vibration.

(Reproduced by courtesy of The Cement & Concrete Association)

Mix proportions to give different degrees of workability for various water-cement ratios are tabulated in Fig. *2b*.

Cube Test (Compression)

When testing of cement was considered, the briquettes made from it were broken by tension, or under a tensile stress.

Concrete, however, is tested by crushing the specimen,

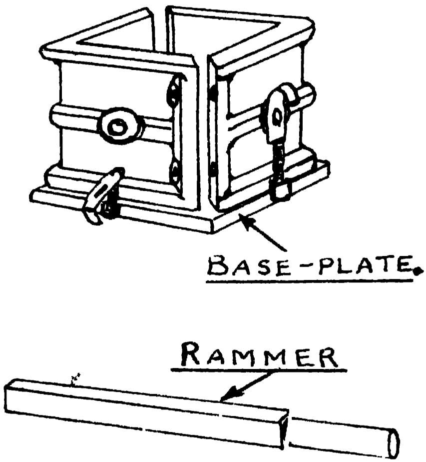


FIG. 50 CUBE MOULD-BOX AND RAMMER

or under a compressive stress. This is because it is a well-known and established fact that concrete is weak in tension but very strong in compression—for which it is used extensively.

In order to perform a compressive test, an iron mould-box of 6-in. cubical shape is employed in which to cast the specimen.

The mould-box is made in halves, with vertical joints to facilitate the removal of the specimen after casting (see Fig. 50).

A 6-in.-cube mould-box is suitable for concrete composed of all aggregates up to and including 1 in. size, but for larger-

sized aggregates, as employed for heavy dams, sea-wall defence works, etc., a 12-in. cube mould is used.

In order to make a cube for testing, a sample of the mix is placed in the mould in three equal layers, each layer being well rammed with the steel ramming bar.

For dry mixes ($1\frac{1}{2}$-in. slump or less) thirty-five strokes should be given to each layer. For wetter mixes the number of strokes given to each layer may be reduced to twenty-five. The ramming of the concrete must be performed methodically, and the strokes should be distributed evenly over the whole surface, and not concentrated in one particular spot.

When very dry mixes are being placed by vibration, this method of making test cubes may not be sufficient to provide proper compaction, in which case some means should be provided for vibrating the cubes so that the concrete is fully compacted and equal to that being used for the job.

After twenty-four hours the cubes are removed from the moulds and stored in damp sand or water until tested. They are tested on their sides, in order to bring two perfectly flat faces in contact with the "platens" of the testing machine.

It is usual to cast three samples at a time, one being tested at three days, another at seven days, and the third at twenty-eight days interval, the crushing strengths at each date being recorded.

For work of importance nine cubes are made (in batches of three) and the average taken.

Fig. 51 depicts a typical compression-testing machine, and Fig. 51*a* shows a specimen in the machine just when the specimen breaks. From this it will be noticed that the fracture adopts a pyramidal shape, which is representative of all concrete cube tests.

In addition to cube tests, it is also customary, especially for thick concrete slabs—such as road works—to cut out, from the finished work, concrete cylinders and send them

for testing at certain periods after construction. This gives an additional indication of the quality of concrete used, or, alternatively, its condition after it has stood and weathered for a period of time, say six or twelve months.

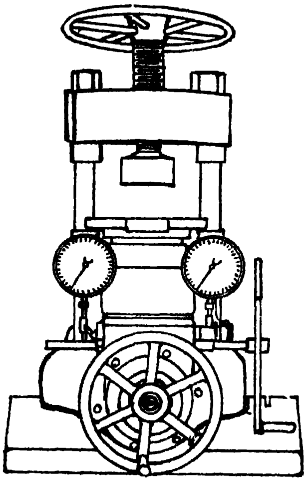


FIG. 51.—COMPRESSION TESTING MACHINE FOR 6-IN. CUBES

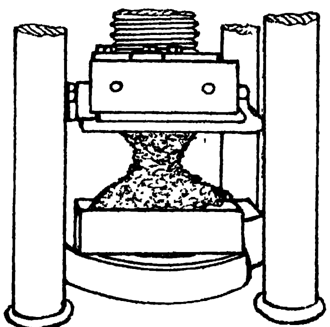


FIG. 51*a*.—ENLARGED VIEW SHOWING PYRAMIDAL FRACTURE OF A CUBE

Fig. 52 gives the B.S. slump test, and Figs. 53 and 53*a* give cube tests, from which full detailed information can be obtained.

FIG. 52

Clause 801 *of B.S.* 114. *Standard Method of Test for Consistence of Concrete (Slump Test)*

This test may be used during the progress of the work for ensuring uniformity in the consistence of concrete.

The test specimen should be formed in a mould in the form of the frustrum of a cone with internal dimensions as follows: bottom diameter, 8 in.; top diameter, 4 in.; height, 12 in. The bottom and the top should be open, parallel to each other and at right angles to the axis of the cone. The mould should be provided with suitable foot-pieces and handles. The internal surface should be smooth.

Care should be taken to ensure that a representative sample is taken.

The internal surface of the mould should be thoroughly clean, dry, and free from set cement before commencing the test.

The mould should be placed on a smooth, flat, non-absorbent surface, and the operator should hold the mould firmly in place, while it is being filled, by standing on the foot-pieces. The mould should be filled to about one-fourth of its height with the concrete which should then be puddled, using 25 strokes of $\frac{5}{8}$ in. diameter steel rod, 2 ft. long, bullet-pointed at the lower end. The filling should be completed in successive layers similar to the first and the top struck off so that the mould is exactly filled. The mould should then be removed by raising vertically, immediately after filling. The moulded concrete should then be allowed to subside and the height of the specimen measured after coming to rest.

The consistence should be recorded in terms of inches of subsidence of the specimen during the test, which is known as the slump.

FIG. 53

Clause 802 of B.S. 114. Preliminary Cube Tests

Method to be used for compression tests on concrete in a laboratory where accurate control of materials and test conditions is possible :

(a) *The Concrete.* The materials and proportions used in making the test specimens, including the water content, should be similar in all respects to those to be used in the work. The cement on arrival at the laboratory should be mixed dry either by hand or in a suitable mixer so as to ensure uniformity, care being taken to avoid the intrusion of foreign matter, and it should then be stored in airtight containers until required. All materials should be brought to a temperature of 58° F. to 64° F. before beginning the tests, and the aggregates should be dry. The quantities of cement, aggregate and water for each batch should be determined by weight to an accuracy of 1 part in 1000.

The concrete should be mixed by hand or in a small batch mixer in such a manner as to avoid loss of water. If the concrete is mixed by hand, the cement and fine aggregate should first be mixed dry until the mixture is uniform in colour. The coarse aggregate should then be added and mixed with the cement and fine aggregate. The water should then be added and the whole mixed thoroughly until the resulting concrete is uniform in colour, and in no case for less than two minutes. If a batch mixer is used, all materials may be placed together in the mixer and mixed thoroughly until the resulting concrete is uniform in colour, and in no case for less than two minutes.

(b) *The Test Specimens.* The test specimens should be 6 in. or 4 in. cubes. Four-inch cubes should not be used when the maximum size of the aggregate exceeds $\frac{3}{4}$ in.

The mould should be of metal with inner faces accurately machined in order that the opposite sides of the specimen are plane and

parallel. Each mould should be provided with a metal base having a smooth machined surface. The interior surfaces of the mould and base should be lightly oiled before concrete is placed in the mould.

Test specimens should be moulded by placing the fresh concrete in the mould in 2 in. layers, each layer being thoroughly compacted with a steel bar 15 in. long and having a ramming face 1 in. square and weighing 4 lb. At least 25 strokes of the bar should be given for each layer, although 35 or more may be necessary for dry mixes in 6 in. cubes.

Where it is proposed to use mechanical vibrators for compacting the concrete, and to allow increased stresses in accordance with clause 303 (a) (iii), the test specimens may be compacted with a mechanical vibrator or by hand.

(c) *Storage of Test Specimens.* Test specimens should be placed in moist air of at least 90 per cent. relative humidity and at a temperature of 58° F. to 64° F. for 24 hours (± ½ hour), commencing immediately after moulding is completed. After 24 hours the test specimens should be marked, removed from the moulds and placed in water at a temperature of 58° F. to 64° F. until required for test.

(d) *Method of Testing.* The tests should be made at the age of the concrete corresponding to that for which the strengths are specified in Tables 1 and 2. Compression tests should be made between smooth plane steel plates, without end packing, and a load should be applied axially at the rate of approximately 2000 lb. per sq. in per minute. One compression plate of the testing machine should be provided with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the plate. Test specimens should be placed in the machine in such a manner that the load is applied to the sides of the specimens as cast.

(e) *Standard of Acceptance.* Three test specimens should be made for each age at which tests are required. The compressive strength should be calculated in lb. per sq. in. from the maximum load sustained by the cube before failure. The average of the strengths of the three specimens may be accepted as the compressive strength of the concrete provided that the difference between the maximum and minimum strengths of the three specimens does not exceed 15 per cent. of the average strength. If the difference exceeds 15 per cent. of the average strength, repeat tests should be made, unless the minimum strength is greater than the strength specified in Tables 1 or 2 as the case may be.

FIG. 53*a*

Clause 803 *of B.S.* 114. *Works Cube Tests*

Method to be used for compression tests of concrete sampled during the progress of the work:

(a) *Sampling the Concrete.* Concrete for the test specimens

should be taken at the point of deposit. To ensure that the specimens are representative of the concrete in the structure a number of samples should be taken from different points. Each sample should be large enough to make one test specimen and should be taken from one point in the work. The location from which each sample is taken should be noted.

(b) *The Test Specimens.* The test specimens should be cubes of the size, and made in the manner prescribed in clause 802 (*b*).

(c) *Storage of Test Specimens.* The test specimens should be stored at the site at a place free from vibration, under damp sacks for 24 hours ($\pm \frac{1}{2}$ hour), after which time they should be removed from the moulds, marked and stored in water preferably at a temperature of 50° F. to 70° F. until the date of test. Where storage in water is difficult, cubes may be stored in wet sand. Specimens which are to be sent to a laboratory for testing should be packed in damp sand, or other suitable damp material, for that purpose and should reach the laboratory at least 24 hours before the test. On arrival at the laboratory they should be similarly stored in water until the date of the test.

(d) *Method of Testing and Standard of Acceptance.* The specimens should be tested in the manner prescribed in clause 802 (*d*) and the standard of acceptance should be as laid down in clause 802 (*e*).

(Clauses 801, 802 and 803 are extracts from B.S. Code of Practice 114 1948 (the structural use of normal reinforced concrete in buildings) and are reproduced by permission of the Council for Codes of Practice for Buildings. Copies of the Code can be obtained from the British Standards Institution, 2 Park Street, London, W.1, and for which the copyright is held by Her Majesty's Stationery Office.)

Another test that can be made is one for determining the workability of the concrete. This is performed by an instrument known as the Wigmore Consistometer—shown in Fig. 54. It is very useful for maintaining the consistency of concrete at the mixer during actual construction work.

The apparatus combines penetration and vibration, is hand-operated, and records on a counter the energy required to "work" the concrete. The number shown on the counter is called the "consistency factor", and no measurements or calculations have to be made—the lower the consistency factor, the more workable is the concrete.

The consistometer comprises a stand 3 ft. high which supports a vibrating platform—operated by a handle at the side of the stand.

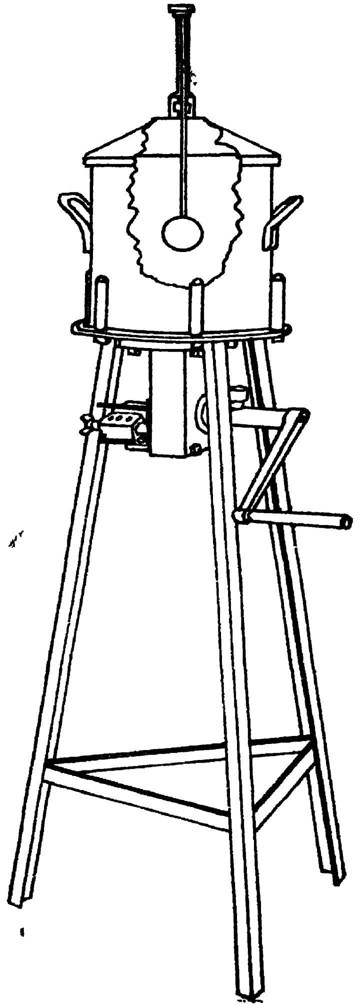


FIG. 54.—WIGMORE CONSISTOMETER

Underneath the platform is a counter which records automatically the consistency factor as the handle is rotated. On the platform is a portable container of $\frac{1}{3}$ cu. ft. capacity, through which a steel rod with a bronze ball moves vertically.

The rod is centralized by a guide-cap which fits into the cover. The apparatus should be kept clean and free from adhering concrete. The rod and ball should be washed clean immediately after each test and dried before re-use.

The operator, after filling the container and replacing the lid, merely rotates the handle and reads the number on the counter.

The test is carried out in detail as follows :—

(*a*) Remove the cover and feed concrete into the container.

(*b*) Replace the container on stand, after ensuring that the platform and underside of container are reasonably clean.

(*c*) Give the handle two complete turns—this will vibrate the container and compact the concrete slightly.

(*d*) "Top up" the container with concrete and level, flush with the rim.

(*e*) Replace the cover.

(*f*) Zero the counter by turning its thumbscrew until the figures ooo appear.

(*g*) Insert the ball and rod through the hole in the cover so that the ball rests on the concrete; then slide the guide-cap into position.

(*h*) Turn the handle at the side of the stand at the rate of one rotation per second.

This operation vibrates the container and causes the rod and ball to sink into the concrete. Continue to turn the handle until the gauge-mark on the rod comes level with the top of the guide-cap.

The figure then shown on the counter is the consistency factor.

An approximate basis for comparison is shown in Fig. 55, in which comparisons are made between consistency factors and approximate slump figures.

FIG. 55

Approximate slump (in.).	Consistency factor.
$\frac{1}{8}$	200
$\frac{1}{4}$	180
$\frac{1}{2}$	150
1	110
$1\frac{1}{2}$	85
2	70
3	50
4	40
5	30
6	20

Suggested factors for various classes of work are : roads (vibrated) 100–150, mass concrete foundations 85–100, thick walls 65–85, thin walls 40–55, and table type vibrators (for concrete block manufacture) 180 minimum.

CHAPTER III

CONSTRUCTION (GENERAL)

Ground Preparation

Since concrete is used as a foundation to carry heavy loads, and in itself weighs approximately 112–150 lb. per cubic foot, the ground on which it is laid must be sound and solid. Any soft spots in the ground should therefore be excavated and filled up with hard-core of some description—such as rubble or broken bricks, otherwise after "casting" the concrete will be liable to settlement and the slab will crack. This is especially so where floor-slabs or concrete roads and aerodrome landing runways are concerned.

After the site has been cleared and set out, a suitable space should be allotted on which to dump the materials (aggregate, sand, etc.). This should be in such a position as not to impede construction in any way, and should be adjacent to the concreting plant and machinery.

Consideration should also be given to the quantities of raw materials likely to be delivered, so as to avoid congestion on the site. An efficient water supply, either piped or stored in tanks, must be arranged, and ample space must also be provided for a damp-proof cement store adjacent to the mixers.

Furthermore, consideration should be given (especially where a new site on virgin ground is concerned) to the question of a temporary access road being made suitable for withstanding heavy lorry traffic delivering materials in wet weather. The ground may be hard and satisfactory in fine weather at the beginning of the job, but it soon becomes vastly different after much heavy traffic has used it during rain.

The question of conveying the wet concrete for placing must also be studied; whether by barrowing it, or conveying in "dumpers" or lorries. Should the ground on which concrete is to be laid be very dry, it may be damped to prevent it absorbing moisture from the concrete.

Having decided upon all the foregoing matters, construction may begin.

The wet concrete, after mixing, should be placed without delay, since it will quickly begin to "set".

Concrete Placing

During the placing the concrete must be compacted efficiently. This is performed by using hand rammers.

Note.—Vibrated concrete is dealt with later.

Care should be taken to ensure that the concrete is well rammed into corners. The ramming or punning is performed by the aid of tools shown in Fig. 6.

The concrete, after being consolidated, should be levelled, either by using a "float" (shown in Fig. 7), or if for a large floor laid in sections, by tamping and screeding. In the latter case forms or shuttering would have been laid previously, on which to perform the tamping and screeding. These operations are dealt with at length in Chapters V and VI.

Concrete Finishing

After tamping and screeding, a smooth surface, if desired, may be obtained by gently sweeping out the marks left by the tamper, for which a broom having soft bristles should be used.

The sweeping must not be performed, however, until the concrete is sufficiently hard to withstand the brushing effect. Planks which form small "bridges" must be placed just clear of the concrete to permit the operator to sweep.

Corner positions, difficult of access for sweeping, can be "hand-floated" over.

Curing

When the finishing has been completed, the concrete should be "cured". This is done by maintaining the surface in a damp state—since it requires several days for concrete below the surface to mature.

If, therefore, the surface is permitted to dry too quickly, cracks will result; it should be kept damp for a period of ten days (for a slab of about 6 in. thick), and longer for thicker slabs.

A water-can fitted with a "rose"-type spray is suitable for small jobs, but for large construction jobs a piped hose supply fitted with a fine sprinkler will be found beneficial.

As an alternative method, hessian canvas may be laid gently on the surface of the work, and watered lightly to maintain it in a damp state.

Another alternative is to sprinkle a thin coat of sand on the work surface, after which it is lightly watered. Both hessian canvas and sand retain water for a considerable time, thereby saving manual labour in having to water frequently.

After use, the sand, if sufficiently clean, may be reclaimed and used for concrete work of minor importance, and hessian canvas can be used indefinitely.

Slow curing is essential, especially where the concrete is exposed to a drying wind or a hot sun.

Incidentally, if sand is used, it has the additional advantage of safeguarding the concrete surface during light frost.

Note.—The foregoing descriptions are the essential factors for placing, finishing, and curing; more detailed information is given later for specific cases.

Working Joints (Expansion, etc.)

Joints must be provided for expansion where the area of concrete is extensive, or where work ceases at the day's end as in the case of road works, etc.

Various proprietary brands of compounds are sold for the

formation of expansion joints, all of which are of a slightly "elastic" nature. The joint may be of plain vertical type or dove-tailed, and the compound is placed between the slab joints.

In order to provide a joint for the end of the day's work, a timber plank of suitable dimensions is placed on edge across the work and securely pegged in position. The concrete is placed along the inner edge of the plank so that it finishes flush with it.

Next day the plank is removed very carefully, in order to avoid breaking off the concrete edges, and work can then proceed. It is advantageous if this joint can be effected at an "expansion" position, thereby providing for both.

The distance at which expansion joints should be constructed depends on several factors, especially the concrete slab thickness. In most cases the distance should not exceed 30 yards. If the area is very large, joints should also be formed at convenient points longitudinally, in addition to transverse expansion joints. If alternate bay-type construction is to be adopted, the working joints will of course be spaced closer to suit the bay sizes.

More detailed information regarding joints is given under the heading of "Roads and Paths" in Chapter VI.

Surface Treatment (Hardening)

Although concrete sets and hardens rock-like, in order to provide an extra hard wearing surface—e.g., heavy type industrial factory floors, roads, airfield runways, etc.—a solution of silicate of soda and water may be applied.

The solution should consist of 1 part of silicate of soda to 4 parts of water thoroughly mixed together.

The application should follow after curing the concrete, say twelve to fifteen days after placing.

The solution may be brushed on, or applied with a mop, but the coating should only be light. Twenty-four hours after applying the first coat, a second one should be given.

This treatment gives a case-hardening effect to the concrete, prolongs its wearing properties, and assists in preventing it dusting—i.e., the surface forming concrete dust during wear and tear.

It is essential to stir the solution in the container occasionally while it is being applied, to prevent settlement.

The coats should be spread as evenly as possible, for which purpose a water-can fitted with a rose-spray is admirable.

Water-proofing

The first essential for procuring a thoroughly waterproof concrete is to ensure that one of dense texture is provided.

The coarse and fine aggregate must be well graded and of high-class quality, and it will be beneficial if slightly more cement is used for the mix.

It is also essential to mix the ingredients thoroughly and to ram well during the placing operation.

Several brands of water-repelling compounds are sold for mixing with ordinary grade Portland cement, or with the rapid-hardening types, but in most cases the waterproofing compounds tend to slightly decrease the ultimate strength of the concrete. Moreover, they may not prove successful unless the foregoing essentials as regards aggregates, grading, and mixing are complied with. As littl water as is reasonably possible should be used for the mix

In addition, concrete for tanks and other liquid containers is frequently lined or "rendered" with some special coating—of which several brands are available—to make it water-tight.

Asphalt, bitumen, and tar products are used in order to treat the outer surfaces of concrete tanks built into the ground to prevent seepage through the concrete walls and floor.

CHAPTER IV

REINFORCED CONCRETE

Elementary Principles

The chief principles concerned with reinforced concrete are, that the concrete takes the compressive stresses and the steel reinforcements cater for tensile stresses.

In a concrete beam or slab the steel reinforcements should, therefore, be nearer the base than the centre axis.

In practice the concrete below the steel reinforcements is

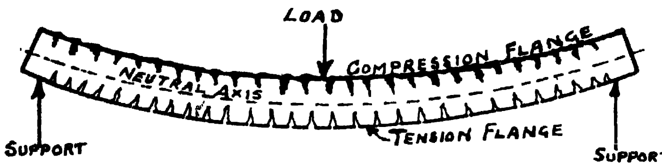


FIG. 56. BENDING OF A RUBBER BEAM UNDER LOAD

provided more for cover protection for the steel than for strength, and in design is therefore practically disregarded from the point of view of strength.

If we consider a plain beam made of hard india-rubber, say 6 in. deep by 2 in. wide, and if the beam be loaded with a fairly heavy load in its central position, this would cause the beam to bend or deflect; and, being of rubber, this deflection would be very noticeable.

It would also be readily seen that the top edge of the beam tended to crinkle or pucker-up—indicating that it is being compressed.

It would be noticed, too, that the lower edge of the beam tended to stretch or open—indicating tension or tensile stress (see Fig. 56).

At some place along the beam's horizontal axis—where the stress changes from compression to tension—there will be no stress. That place is known as the " neutral axis ".

Here, then, we have the elementary principle of a reinforced-concrete beam, since the stresses are applied similarly, but in concrete the deflection or bending is, of course,

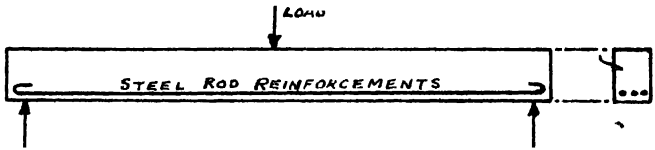


FIG. 57.—SIMPLE REINFORCED CONCRETE BEAM SHOWING STEEL RODS USED TO RESIST TENSION

not so pronounced as that seen in india-rubber taken for our example (see Fig. 56).

The same principles of bending (in which both tensile and compressive stresses are developed) apply also to reinforced-concrete pillars and walls of buildings, since wind pressure acting on their surfaces—coupled with the loads

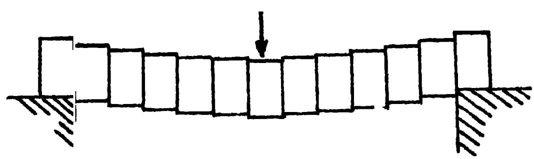


FIG. 58.—VERTICAL AND HORIZONTAL SHEAR FORCE ACTION

derived from the roof—tend to cause bending, which is resisted by the steel, and the concrete resists the direct compressive stresses.

Fig. 57 shows a simple concrete beam with steel reinforcements in its tension flange position, and resisting deflection.

Figs. 58, 59, 60, and 61 illustrate what happens in a loaded beam, but in this case caused by shear force, which also produces tension.

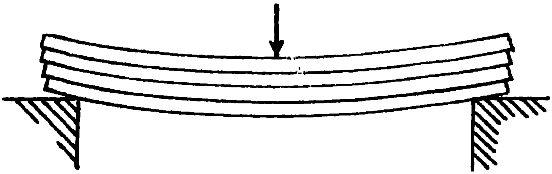


Fig. 59.—Sliding Tendency of Beam's Components

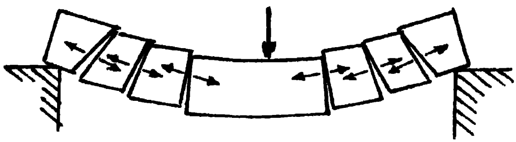


Fig. 60.—The Two Types of Shear thus Tend to Produce Tension which would Result in Failure

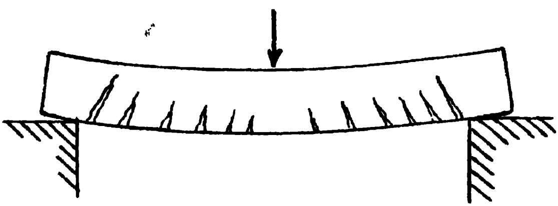


Fig. 61.—In a Plain Concrete Beam Cracks would Occur

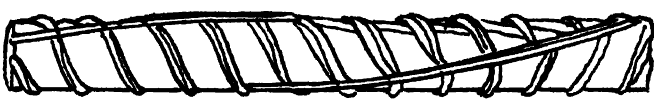


Fig. 62a.—Tentor Patent Reinforcement Bar

Fig. 62.—Round Steel Bar Fig. 63.—Square Steel Bar

Reinforcements (General)

Steel rods, of circular cross-section, are the most common form of reinforcement used. These vary in diameter from $\frac{3}{16}$ in. up to 2 in., the larger sizes being used for heavy duty (see Fig. 62).

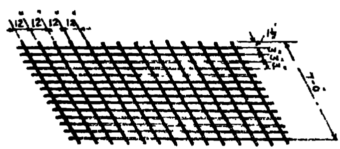


FIG. 64.—LONGITUDINAL MESH (SHEETS)

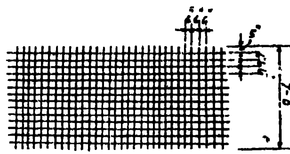


FIG. 65.—6-IN. SQUARE MESH (SHEETS)

Fig. 62*a* shows the "Tentor" patent reinforcing bar, which has two parallel longitudinal ribs and transverse diagonal ribs formed integrally, and arranged in a herring-bone pattern.

It is claimed for this design that it ensures a high bond stress between the steel and the concrete. Although it is of Danish origin, this design is now being manufactured by several British firms under licence.

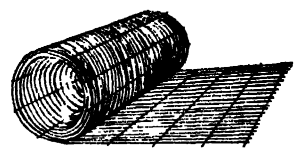


FIG. 66.—MESH IN ROLL FORM

Bars of square section may be used, but these are less common (Fig. 63).

In addition, mesh-type steel reinforcement is employed extensively—especially for road-slabs, building floors, etc. In some designs the mesh is of square formation, and of diamond pattern in others.

The well-known B.R.C. fabric, similar to that shown in Figs. 64, 65, and 66, is also electrically cross-welded at each intersection point.

The steel from which the fabric reinforcement is made is hard-drawn steel wire, which complies with British Standard Specification No. 785.

FIG. 66*a*

B.R.C. Standard Sizes of Reinforcement Fabric
Dimensions, Strength, Weight.

B.S. Ref. 1221A.	B.R.C. Ref. No.	Distance centre to centre of wires.		Gauge of wire.		Sectional area of wires per foot width (sq. in.).	Safe tensile strength at 27,000 lb. per sq. in. (lb. per ft. width).	Weight of fabric (lb. per sq. yd.).
		Main (in.).	Cross (in.).	Main S.W.G.	Cross S.W.G.			
101	F	3	16	4/0	4	0·5027	13,500	16·35
102	2	3	16	3/0	4	0·4347	11,700	14·27
103	3	3	16	2/0	6	0·3805	10,300	12·31
104	4	3	16	1/0	6	0·3298	8,900	10·76
105	5	3	16	1	6	0·2827	7,600	9·32
106	6	3	16	2	7	0·2393	6,500	7·88
107	7	3	16	3	8	0·1995	5,400	6·57
108	8	3	12	4	9	0·1691	4,600	5·67
109	9	3	12	5	10	0·1412	3,800	4·71
110	10	3	12	6	10	0·1158	3,100	3·94
112	12	3	12	8	12	0·0804	2,200	2·72
113	14	3	12	10	12	0·0515	1,400	1·83
121	61	6	6	1	1	0·1414	3,800*	8·65
122	62	6	6	2	2	0·1197	3,200*	7·32
123	63	6	6	3	3	0·0998	2,700*	6·10
124	64	6	6	4	4	0·0845	2,300*	5·17
125	65	6	6	5	5	0·0706	1,900*	4·32
126	66	6	6	6	6	0·0579	1,600*	3·54
130	610	6	6	10	10	0·0257	700*	1·58

* In each direction.

Fig. 66*a* gives a table of dimensions, weight, etc., for standard sizes of B.R.C. reinforcement fabric or mesh.

When mesh reinforcement is being placed in position it should overlap at least two mesh sizes, and the edges should

FIG. 67.—"TWISTEEL" BAR

stop off 2 in. from the edge of the concrete, so as to allow concrete cover protection.

Some types of mesh are composed of square bars twisted longitudinally, thereby forming a helix on them. In this case it is claimed that a better bonding is established in the surrounding concrete (see Fig. 67).

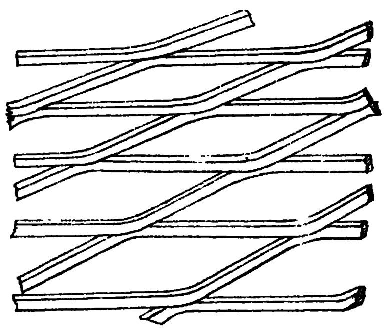


FIG. 68.—EXPANDED METAL MESH REINFORCEMENT

Another popular type of reinforcement, known as "expanded metal", is formed by pressing a diamond-shaped pattern from a steel-sheet plate (see Fig. 68).

Some types of square or rectangular mesh are formed merely by interweaving the cross members alternately over and under the longitudinal bars. Other types are electrically "spot welded" at each point of the square mesh, thereby providing additional rigidity for the whole sheet.

Steel-mesh reinforcement may be supplied either in roll form—to cut to size as required—or in flat sheet form ready cut to size and shape.

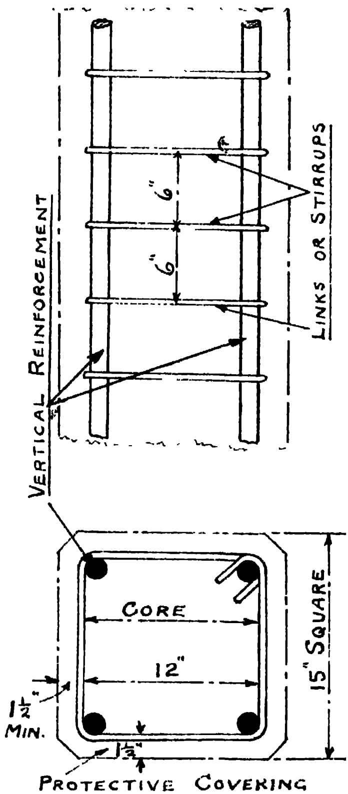


FIG. 69.—COLUMN REINFORCEMENT (LINK TYPE)

Square reinforcement mesh composed of rods loosely interwoven—i.e., not spot welded—may be reshaped by pulling the bars to form diamond mesh. This is sometimes

convenient for re-forming a square sheet so as to fit it into an acute corner of a building floor without recourse to cutting and wastage.

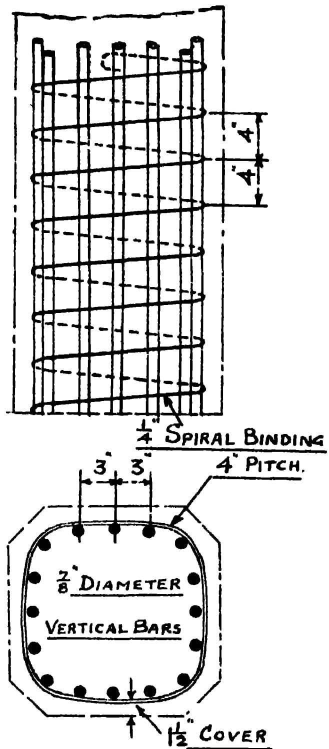


FIG. 70.—COLUMN REINFORCEMENT (SPIRAL TYPE)

Reinforcements for columns or pillars are usually provided —for square-type columns—by placing four steel bars vertically, one for each corner position. These are surrounded by horizontal bars, called " stirrups " or " links ", which form rectangles, and are secured to the verticals by

tying them with thin wire—known as "binding wire". The stirrups are positioned at suitable intervals or "pitches" for the complete length of the column (see Fig. 69).

For columns of octagonal section, six or more vertical bars are used. These are surrounded by either circular

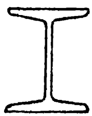


FIG. 71.—ROLLED STEEL JOIST

FIG. 73.—STEEL TROUGHING

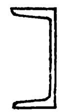


FIG. 72.—ROLLED STEEL CHANNEL

BRIDGE REINFORCEMENTS

stirrups or by a steel bar of spiral or helical formation (see Fig. 70).

The reinforcements for heavy highway or railway bridges are often provided by embedding rolled-steel joists (or "I" beams) and rolled-steel channels in concrete. In alternative designs "steel troughing" is used for the reinforcement (see Figs. 71, 72, and 73).

Bending of Reinforcements

Steel reinforcing rods are usually bent at their ends to form hooks in order to provide extra security in bonding and to permit of other rods passing through the loops at right angles to the former (see Figs. 71*a* and 72*a*).

FIG. 71*a*.—TYPICAL REINFORCING ROD BENT FOR USE

The ends of rods $\frac{3}{16}$ in. or $\frac{1}{4}$ in. in diameter may be bent manually, for link or stirrup formation, etc. However, special machines, either operated manually or by hydraulic pressure, are used for bending the larger-diameter bars or rods (see Fig. 73*a*).

Most types of pipe-bending machines are also suitable for use on steel rods.

Pliers are used for "twisting" or tying the binding wire.

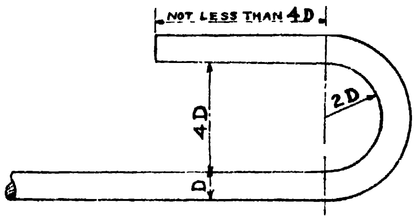


FIG. 72a.—STANDARD HOOK BEND

The bending is mostly performed on the steel rods while cold, but bars of large diameter may require to be heated, after which any loose "scale" must be removed.

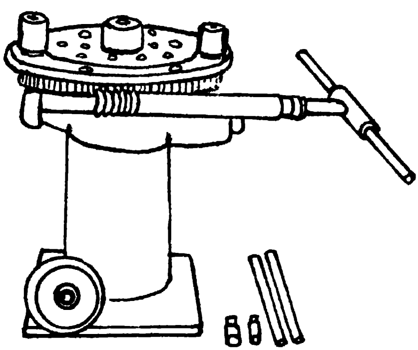


FIG. 73a.—BAR BENDING MACHINE

It is essential also that after the bars have been bent and made ready for use, and before being placed in position, they are brushed thoroughly with a stiff wire brush to remove any rust or mill-scale.

Every precaution should also be taken to ensure that the

concrete is placed as soon as possible after the reinforcement has been erected, or rusting, which interferes with the bonding of the concrete to the steel, may occur.

Fixing Reinforcements

The fixing of reinforcement wire mesh in slabs, floors, or roads is a relatively simple matter, since it can be laid on packings at the required heights (see Fig. 74).

If in sheet form, the ends and sides should overlap those

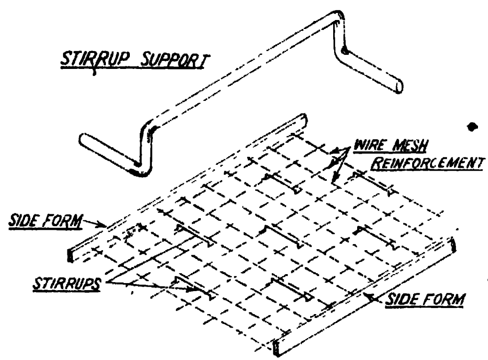


FIG. 74.—STIRRUP SUPPORT TO KEEP REINFORCEMENT IN POSITION

adjacent to them, and if in roll form, after laying out one roll flat, the next should overlap slightly during its unrolling and subsequent placing.

The amount of overlap depends on the size of sheet, and it is advisable to overlap by at least two sizes of mesh. For work of importance the overlaps should be secured by tying them with binding wire to prevent displacement.

Great care must be exercised during the positioning of reinforcements for concrete walls, especially if the walls are of thin formation, since the slightest displacement will cause trouble.

Where oil or grease is used on the shutters (or form-work), care must be taken to ensure that this does not contact the steel reinforcements, or it will prevent bonding with the concrete when placed.

In order to retain bars in position during their fixing

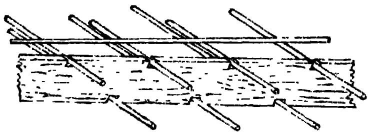


FIG. 75.—TEMPLATE BOARD ASSISTS IN FIXING STEEL BARS

and tying, supports or template-boards may be used, as shown in Fig. 75. This is of special importance for slabs or floors.

During the placing, and after aligning the bars, they must be securely tied at all cross-joints, etc. A typical tie formation is shown in Fig. 76.

Soft iron wire of No. 16 S.W.G. (Standard Wire Gauge)

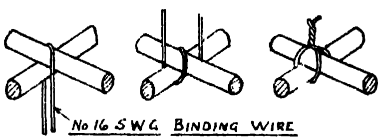


FIG. 76.—FORMING JOINT TIE

is used for tying, and any surplus ends are cut off by using wire-cutting pliers. For cutting mesh reinforcement, special heavy duty hand-shears—called bolt-cutters or "croppers" —are used (see Fig. 77).

A trestle-type stand—similar to that shown in Fig. 78—will facilitate fixing and tying the links or stirrups for column reinforcing bars. By this means most links can be fixed—except those near the ends, which can be positioned and tied after removing the skeleton framework from the

stand, since by then the framework will be sufficiently rigid.

An alternative is to construct one trestle for easy detach-

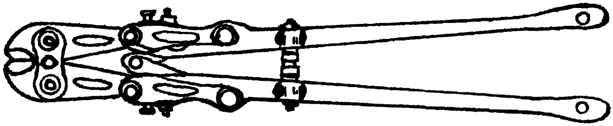


FIG. 77.—BOLT CROPPER FOR CUTTING WIRE MESH

ment from the diagonal bracings by fitting bolts with wing-nuts or thumb-nuts.

When fixing "skeletons" for very long columns it is

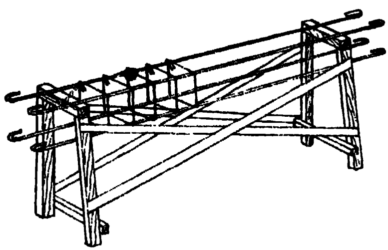


FIG. 78.—STAND FOR FIXING REINFORCEMENTS

advisable to have a third trestle positioned between the end two in order to provide additional support and to prevent sag.

Formwork or Shuttering

For the construction of walls, columns, slabs, tanks, etc., formwork must be erected between which to place the concrete.

Timber boards are often used for this, and are supported at suitable intervals by both vertical and horizontal battens, and struts secured into the ground. Steel-plate shuttering is also now employed extensively.

Where used, timber must be of suitable thickness to prevent warping, and the battens and struts, etc., must be of ample size and strength to provide rigid support. Furthermore, every precaution must be taken to ensure that when the concrete is deposited (or placed), neither the reinforcements nor the shuttering are displaced by the weight of concrete or by ramming.

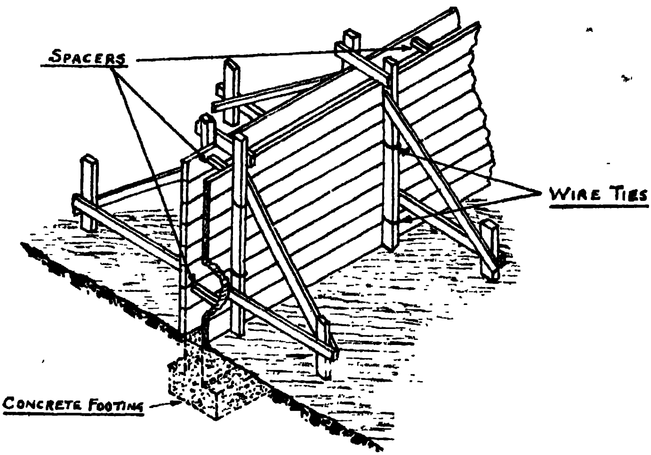


FIG. 79.—TYPICAL TIMBER SHUTTERING FOR WALLS

In order to carry the loads from walls, building roof, etc., bases (or footings) must be constructed to distribute these loads over a greater area in the ground. The footings are, of course, made first—before erecting the shuttering in which to cast the walls.

"Spacers" are placed between the side shutters to maintain the latter at the specified distance apart. Timber may be used for this purpose. After concreting and dismantling of the shutters has been completed, these spacers are driven out, and the holes filled up with "grout"—a mixture of sand, cement, and water.

A better method, however, is to pre-cast spacers in concrete by moulding them. These may be left permanently in the wall, thereby forming part of it. Wire "ties" are also sometimes placed through the side-shutters to retain them in position.

After casting the concrete, and during shutter dis-

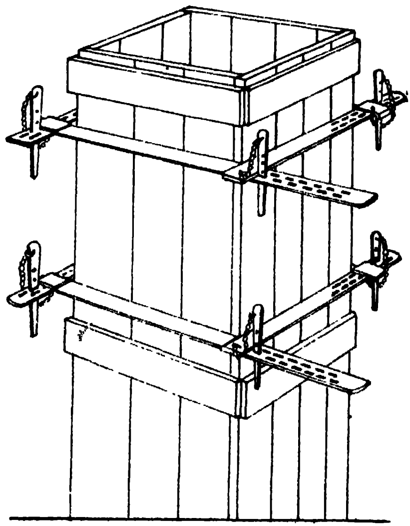


FIG. 80.—ADJUSTABLE STEEL COLUMN CLAMPS FOR TIMBER SHUTTERING

(Reproduced by courtesy of Acrow (Engineers), Ltd.)

mantling, the ends of the wires are cut off, as close in to the wall as possible, and the places filled up with grout.

During erection of the shuttering, the steel reinforcements are also placed and firmly secured in their relative positions. Here again spacers and ties are placed at intervals as required (see Figs. 79 and 80).

During these operations frequent inspections should be made to ensure correct alignment of both shutters and reinforcements.

Moreover, the inner faces of the shutters should be oiled, greased, or lime-washed in order to facilitate their removal later. Special types of oil which have no adverse effect on the concrete surface are supplied for this purpose. If plain timber is used, the concrete is likely to stick to it.

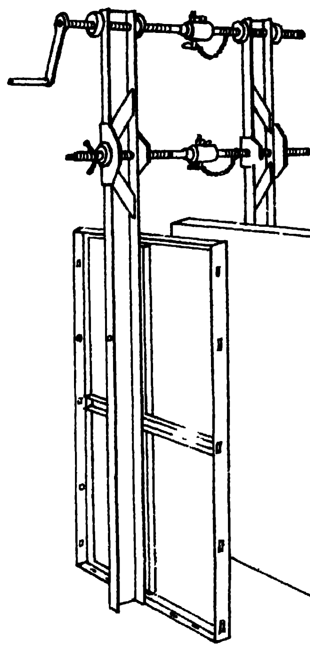


FIG. 81.—ACROW ADJUSTABLE STEEL WALL SHUTTERING CLAMPS

Steel shuttering, in the form of panels, is now used extensively. This is supported both laterally and vertically at suitable intervals by stiffening members (see Figs. 81, 82, and 83). The panels are supplied in standard form, with flanged edges suitable for bolting together or securing by steel wedges, etc.

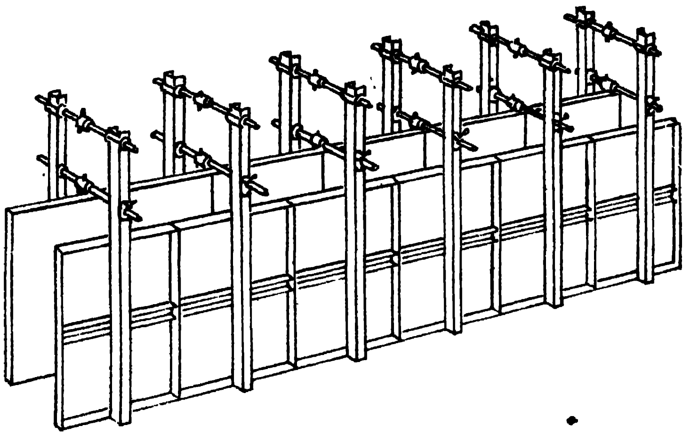


FIG. 82. -ACROW STEEL SHUTTERS FOR WALLS

(Reproduced by courtesy of Acrow (Engineers), Ltd.)

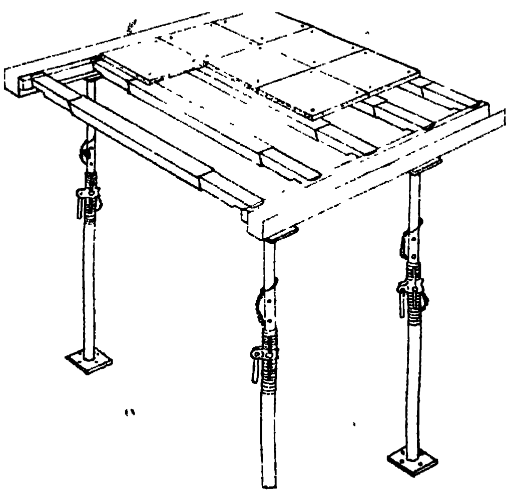


FIG. 83.—ACROW ADJUSTABLE FLOOR CENTRES AND PROPS

(Reproduced by courtesy of Acrow (Engineers), Ltd.)

After dismantling, all shuttering should be immediately cleaned and oiled ready for further use, since the "green" concrete is then more easily removed.

Expansion and Contraction

Like most other materials, concrete is susceptible to expansion and contraction when subjected to temperature fluctuations, although to a lesser degree than some materials.

The coefficient of expansion due to changes of temperature is about 0·000006 per degree Fahrenheit, and closely resembles that of steel. Moreover, concrete changes in volume during hardening, and this change is more pronounced when the concrete is richer in cement used for the mix.

When concrete is hardened in air it contracts approximately 0·0005 of its length, and when hardening in water it expands about 0·0001 of its length.

In large concrete structures such expansion and contraction must be provided for, or cracks will develop later.

Expansion Joints

These take many different forms, each depending on the size and class of job.

For large floor-decks of buildings the joints may be formed by inserting compressed cork, bitumastic felt, or various rubber compounds between the slabs, at suitable intervals, say of 70–100 ft.

In reinforced-concrete walls the joints are sometimes made by forming a dovetail vertically in the concrete and inserting in it one of the above-mentioned compositions.

For ground-floor slabs the joints are often made by placing horizontal round steel bars at intervals of 2 ft. or 2 ft. 6 in., and by concreting them into the slab at one side of the joint while the projecting ends are lapped in grease-proof paper prior to concreting the adjacent slab. The space between the two slabs is then filled (or run in) with bitumen or bituminous asphalt (see Fig. 84).

In large reinforced-concrete bridges provision for expansion is sometimes made by casting (integrally with the

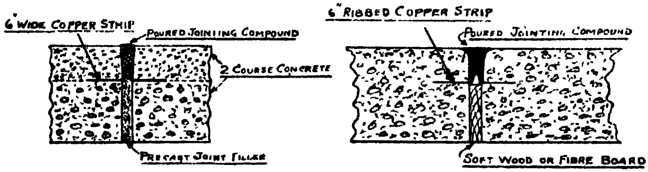


Fig. 84.—Typical Water-Proof Expansion Joints

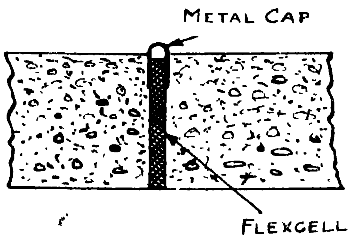


Fig. 84a.—Expansion Joint

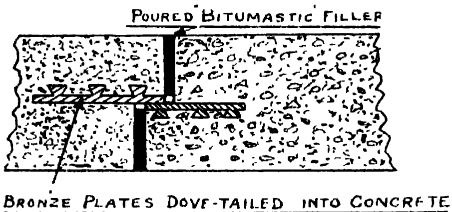


Fig. 85.—Bridge Slab Type Expansion Joint

concrete) bronze plates at intervals in pairs, so that the upper surface of the one plate slides on the mating surface of the other (see Fig. 85).

Stripping of Shuttering and Finishing of Concrete Work

Care must be exercised in the stripping of concreted work, since there may be a tendency for the shutters to

stick, in spite of their having been greased prior to concreting. The shutters should be removed warily, and any board-marks (or bad places), honeycombing, etc., in the concrete at once made good.

Honeycombing or harshness in concrete is often caused by either insufficient ramming (or vibrating) of the concrete during its placing, by using too dry a mix, or poor shuttering which permits loss of matrix. It is sometimes seen in corners where ramming has been neglected.

In order to perform this finishing or making good, work should start as soon as possible, while the concrete is still "green"—as it is termed.

The places concerned should first be sprinkled with clean water, after which a wood float should be used to "point" up by using liquid grout or mortar composed of cement, sand, and water. If carried out immediately after stripping, the mortar is more likely to adhere well and to provide a good finish.

Ridges caused by board joints can also be rubbed down while green, or they may be allowed to harden thoroughly and be erased later by using an emery stone (or grinder).

Many pneumatically or electrically operated grinding machines are available for this purpose, but for small jobs hand emery stones are suitable.

Bush Hammering

In order to expose the bare aggregate, and thus provide a decorative finish, a "bush hammer" (see Fig. 86) may be used on finished concrete.

This tool chips away the outer surface, thereby exposing the aggregate. Bush hammering is often performed on panels of walls, bridge parapets, etc. If well executed it gives a pleasing appearance. On completion of the bush hammering, the panel should be well washed, preferably by means of a hose-pipe, to dislodge any dust or small chippings.

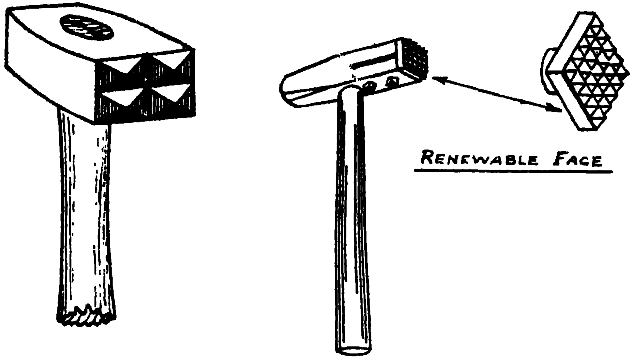


FIG. 86.—TYPES OF BUSH HAMMER

Surface Finishes

These may also be obtained by washing with a dilute acid, or by brushing with a stiff wire brush.

"Gunite" Spray System

The plant consists of a "cement gun", flexible hose, and a metal container. Previously mixed DRY sand and cement are stored in the container.

Compressed-air feeds the mixture from the container along a hose to the cement gun-nozzle, where it is joined by a spray of water from a parallel hose-pipe outside the casing.

The operator directs the spray as required on to the surface of the work.

It is claimed that this process provides a hard, dense surface finish.

Non-slip Surface Finish

It is sometimes advisable to include "abrasives" in the surface of concrete floors.

Silicon carbide (in grain form), known commercially as "Carborundum" or "Crystolon", or aluminium oxide (in

grain form), known as " Alundum " or " Commercial Floor Grit A ", are used extensively for this purpose.

The abrasives may either be mixed with the cement, or lightly sprinkled on the concrete surface and trowelled in during the finishing process.

These abrasives are equally suitable for facing pre-cast concrete paving-slabs.

CHAPTER V

CONCRETE FLOORS (FOR BUILDINGS, ETC.)

THESE may be of either the "alternate-bay" or "continuous" slab construction, depending on several factors, such as the size and thickness of floor concerned, and accessibility for construction.

In both cases it is first necessary to peg out the ground

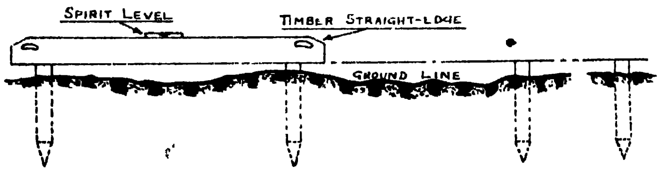


FIG. 87.—PEGGING OUT LEVELS FOR EXCAVATION

and drive in the pegs to the required levels. If a slope is to be provided for drainage purposes, this must, of course, be allowed for during the driving of the pegs to their respective levels. For such work timber pegs of 2-in. or 2½-in. square section and of the desired length will be found suitable (see Fig. 87).

Formwork of either timber or steel "shutters" must then be provided to form the boundary and levels of the concrete slab. The formwork must be rigidly fixed, so as to withstand the pressure when the wet concrete is later deposited and rammed for consolidation, or, if mechanical vibrators are to be used, to withstand such vibration thereby created (see Fig. 88).

Should the ground be very dry, or of an absorbent character, "sisal" paper (i.e., stout brown paper with

fine fibre mesh treated with a bitumen solution) is sometimes placed on the soil to prevent the ground absorbing moisture from the wet concrete when placed.

If reinforcement steel is to be used, it should next be placed in the specified position. For this, small precast blocks of concrete or steel stands as shown in Fig. 74 may be used on which to place the reinforcements, and which retain them at the correct height.

The wet concrete should then be deposited by starting from a corner position. Which method is adopted for

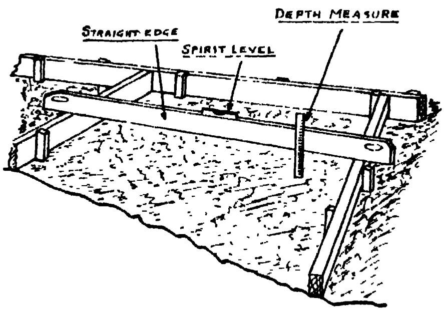


FIG. 88.- FORMWORK AND EXCAVATION

conveying the concrete from the mixer to the formwork will depend on the size of job, plant available, etc.

For small jobs this is usually performed by barrow, skip, hoist, or chute. On larger jobs the wet concrete may be conveyed in steel (side-tipping) wagons, or by pumping it through suitable-sized tubes. While being deposited, in order to avoid the possibility of " air pockets " being formed —which may cause " honeycombing "—the concrete should not be allowed to fall from a great height. Nor should the concrete be placed over too large an area at once. It should be built up to the desired thickness, ready for consolidating by " tamping " or vibrators.

During the depositing it is advisable also to ram the

concrete by hand rammers, especially in the corners and base near the formwork. Care must be taken, however, not to dislodge either the steel reinforcements or the packings on which they were originally placed.

When a sufficiently large area has been covered by the deposited concrete and built up to the required slab thickness (or preferably slightly thicker) it is ready for "tamping".

Note.—Prior to the tamping operation it is customary to level the concrete by using a spade.

Tamping

This is performed by using a "tamper", which consists of a stout timber board with handles fitted at both ends (see Fig. 89).

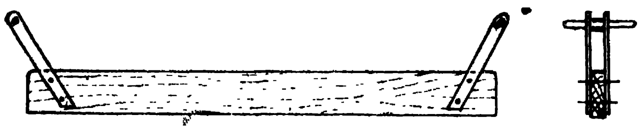


FIG. 89.—TIMBER HAND TAMPER

For small concrete slabs the tamper board may be of, say, 6-in. by 2-in. cross-section, and slightly longer than the slab concerned. Its lower edge must be planed smooth, and must be perfectly flat and level.

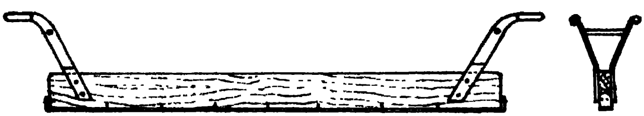


FIG. 90.—STEEL SHOD HAND TAMPER

For larger work the tamper board may be of 8 in. by 2 in. or 9 in. by 3 in. timber (usually pine) and fitted with a $\frac{3}{16}$ in. or $\frac{1}{4}$ in. thick steel strip at its lower edge (see Fig. 90).

The steel strip is usually secured by countersunk-headed wood-screws at suitable intervals, but since, during the

action of tamping, the steel becomes gradually worn down, a better construction is to use countersunk-headed bolts which pass completely through the 9-in. timber, similar to the smoothing board shown in Fig. 90*a*. These are more easily dislodged than wood-screws, the slotted heads of which become worn down with use. The bolts can then be

FIG. 90*a*.—SMOOTHING OR FINISHING BOARD

drifted out completely for renewal of the steel strip. In Fig. 91 a power-vibrated tamper is shown.

In use, a manual tamper is held firmly by an operator at each end, and the tamper board spans the bay or slab, the formwork thereby providing a base or guide for the tamper. To begin, it is essential for both operators to work in rhythm, so as to beat and compress the concrete uniformly, by

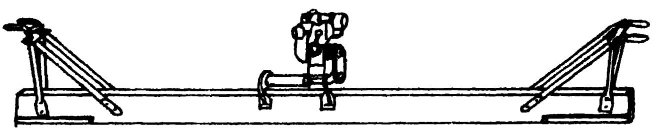


FIG. 91.—POWER VIBRATED TAMPER

lifting the board and bringing it down smartly, or " bumping " the wet concrete.

After having been given a few such blows, the concrete should be screeded—or " sawn ", as it is sometimes called—by moving the tamper-board to and fro, first towards one operator and then towards the other. During the screeding action the board should be brought gradually forward towards the point where further concrete is being deposited in the bay.

During tamping and screeding any hollow places in the

concrete surface must be filled in by adding more concrete. The area must be bumped down and screeded once more.

The tamper board should finally be returned to the original starting place, and the whole area *lightly* tamped over again. This final action is often known as "half-inching", because the operators advance about half an inch at each tamping stroke.

Note.—It will be realised from the description of the size of timbers and steel strips used in constructing a tamper board for large work that it weighs approximately 7 lb. per foot run. Tamping by hand is therefore laborious, and it is advisable to have two or more pairs of operators trained for this work, who can then be relieved at intervals, and thus given a rest by changing to lighter duty alternately.

After tamping the floor surface as described, it may be left to set and harden, but a relatively rough surface will result which may be desirable for some jobs, such as heavy vehicle garages, warehouse floors, and some classes of roads. If, however, a smooth surface is desired, after tamping the slab may be lightly brushed by using a soft-bristle flat broom, having a head of, say, 18 in. by 4 in., and moving it gently to and fro to remove the tamper marks and any scum that may have accumulated.

This work of brushing is best performed by placing a stout plank across the slab and packing it at both ends to clear the concrete. This will allow a man to walk along the plank to brush or sweep.

Brushing should never be attempted while the work is too wet, and it is preferable to allow it to dry out slightly after tamping has been completed. No definite time can, however, be specified for this, since it depends on climate conditions, etc., and is best decided by experience.

The work is then ready for curing, as described previously in Chapter IV.

It is, however, essential, at all stages of depositing the concrete, tamping, and sweeping, to ensure that the form-

work remains rigid and secure, and frequent inspections should be made for this purpose.

Fig. 91*a* shows a Rapier Pan vibrator. This can be

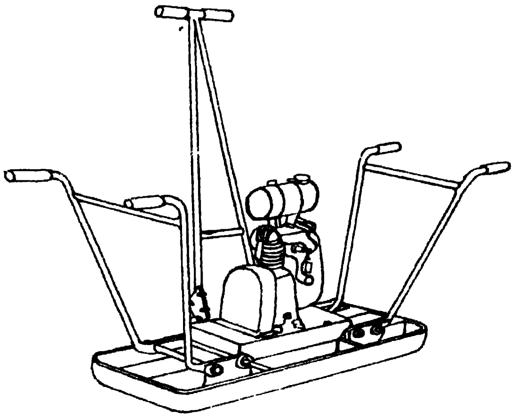


FIG. 91*a*.—RAPIER PAN VIBRATOR
(Reproduced by courtesy of Ransomes & Rapier, Ltd.)

employed for small concrete strips, patches, etc., for vibrating and finishing the work.

This machine is very suitable for vibrating stiff or dry mixes, and is easily handled by two operators.

The pan vibrator is driven by a four-stroke, blower-cooled petrol engine, which is economical to maintain.

CHAPTER VI

CONCRETE PATHS AND ROADS

Paths

For constructing light concrete paths suitable for housing estates, etc., for pedestrian traffic only, the same principles may be followed as given in the previous chapter. The slab, however, need not be so thick as for warehouse floors;

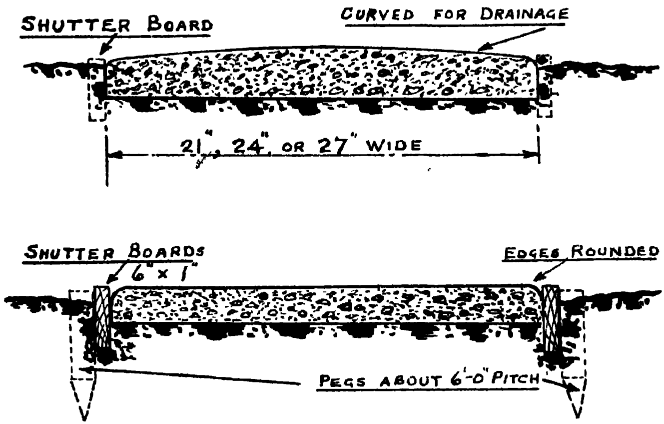


FIG. 92.—TYPES OF CONCRETE PATHS

nor does the mix require to be so rich. The usual slab thickness for paths is 3 or 4 in., and a mix of 1 part of cement to 6 parts (or even 8 parts) of shingle or ballast may be employed. Nor is there any call for heavy tamping, since the concrete can be consolidated sufficiently by efficient hand ramming, spading to a preliminary smooth finish, and finished by screeding the surface. However, the

better the materials and workmanship, the better will be the job.

Since paths have to withstand all weathers, it is essential that a smooth surface be made, for if small hollows or holes remain in the surface, rain collects during winter, and is likely to freeze, thereby causing expansion, followed by contraction during a subsequent thaw, when the surface is liable to disintegrate or peel off (see Fig. 92).

Construction

In order to construct a path, and if the ground is reasonably level, all that is necessary is to erect edge shutters or forms. These may be of 1-in.-thick boards of the desired depth to suit the path thickness; the path will then be slightly above normal ground level.

The boards should be fixed in position by driving pegs into the ground on alternate sides, and spaced about 6 ft. apart. Later, as concreting proceeds, the inner pegs should be withdrawn, since the pressure exerted by the concrete will then maintain the edge-boards in position.

In certain cases it is preferable to use deeper boards and to drive their lower edges into the ground, after spading out a shallow channel. This is especially so if the ground is covered by weeds or turf, etc. These must be removed with the surplus soil and the ground levelled or skimmed by spading. It is not necessary to use " sisal " paper prior to concreting for light paths, but if the ground be dry and of a sandy nature it is advisable to damp it by hosing, or sprinkling from a water-can having a rose-spray, in order to prevent absorption when the concrete is deposited.

For small jobs the mixing is usually performed by hand on a clean mixing-board, close to the work, and the wet concrete can be conveyed by means of either bucket or barrow.

During the depositing of the concrete it should be well rammed, especially near the edge-boards.

A length of 2 in. by 1 in. wood about 1 ft. long is suitable

for the ramming. It should next be levelled with a spade or shovel, and finished off by screeding.

To perform the screeding a board 1 in. thick by 6 in. wide may be used, and it is preferable to curve the lower edge slightly in order to form a small " camber " on the concrete surface instead of leaving it flat (see Fig. 93). This will prevent rain from settling on the surface.

The screed-board must be of suitable length to span comfortably the edge-boards. If the path is only 1 ft. 9 in. to 2 ft. 3 in. wide, screeding can be done by one man.

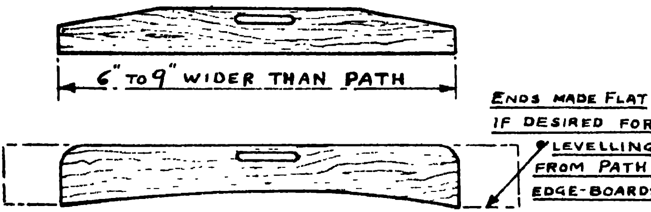


FIG. 93. TYPES OF SCREED BOARD FOR PATHS

After screeding has been completed it is preferable to bevel or round off the concrete edges of the path by using a trowel, since, if left with sharp corners, the edges are liable to be chipped off during later use and after the shutter-boards have been removed.

All that now remains to complete the work is to cure the concrete. This may be done by damping it occasionally with a rose-type watering-can or hose spray. This is essential during hot sunny weather or drying winds.

When finally the concrete is set and hardened, the shutter-boards may be removed, their spaces filled in with earth, and the concrete edges " backed up ", thus forming haunches by ramming the soil alongside (Fig. 94).

Short paths may be constructed without expansion joints, but for those exceeding 50 or 60 ft. in length expansion joints should preferably be made at those intervals. A common form of joint is made by placing a wood strip

on edge; the wood should be creosoted before use and be at least $\frac{1}{8}$ in. thicker than if bitumen were used as a "filler" for the joint. This process however, is more applicable to long "drives" for private houses or large estates.

FIG. 94.—FINISHED PATH

CONCRETE ROADS

General

The type and construction of these depend on the amount and class of traffic to be carried. Arterial or trunk roads must, therefore, be of heavier construction than, say, private roads on housing estates, which cater for only moderately light traffic, such as private cars and occasional tradesmen's vans, in addition to pedestrian traffic.

Incidentally, the technical width of a so-called "road" is the distance between its boundary fences, hedges, or walls, and what is often commonly called the road is technically termed the "carriage-way".

Considering for a moment the case of a new by-pass road—this may have its boundary fences 100 ft. apart, and may comprise dual (one way) carriage-ways, each 20 or 22 ft. in width. The road may also have footpaths and cycle-tracks on one or both of its sides.

The carriage-ways, footpaths, and cycle-tracks often have grass verges between them.

Many of the details given earlier (under the heading of floor-slab construction) apply equally to road construction, especially if the roads are of relatively small size.

However, in concrete-road construction many other features have to be considered, such as surface-water drainage, camber, inclines, curves, super-elevation at sharp corners, and bends in the road (i.e., raising one side of the

slab gradually at the approach of the bend, increasing the rise at the maximum bend, and decreasing it correspondingly as the bend enters a straight section again), vertical curves, dips, S bends, etc., some of which require transition curves to facilitate fast-moving traffic entering the various bends from a straight section, and for leaving the latter again.

Moreover, the laying of gas, water, electric, and P.O. telephone services frequently have to be effected during the construction of new roads.

The curves, super-elevation, etc., are taken care of during the setting-out process, and do not alter the type of slab construction, but sometimes complicate the construction methods.

Types

The roads may be of various types of construction; some of the most common are: (*a*) the alternate bay, with diagonal joints (i.e., joints set at an incline), as shown in Fig. 95; (*b*) the alternate bay, with straight joints, as in Fig. 96; (*c*) the continuous slab (Fig. 97); (*d*) the staggered bay with longitudinal joint.

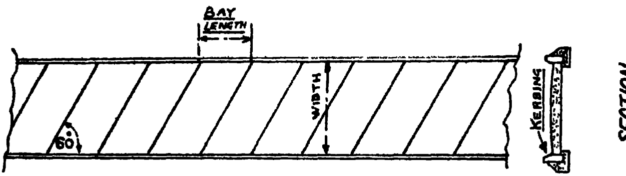
Another type is that having a mass concrete foundation, but a tarmacadam or bituminous carpet surface.

Types (*a*), (*b*), (*c*), and (*d*) will now be considered in more detail.

Alternate Bay—Type (*a*)

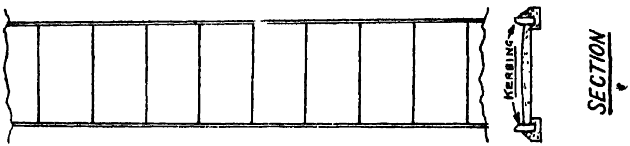
For road widths of 18, 20, 24, and 30 ft., the bays—which are of those widths—are constructed, or cast, alternately. This means that, considering a series of bays, numbered consecutively 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and so on, bay numbers 1, 3, 5, and 7 would be cast first, thereby leaving spaces for the even numbers—2, 4, 6, 8, and so on—to be cast later.

The object of staggering the joints is to avoid the wheel-loads from heavy traffic being transmitted to the joint



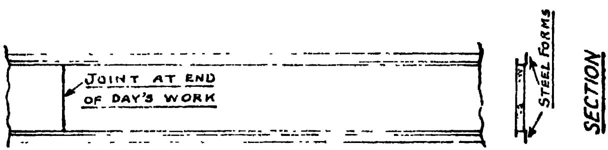
ALTERNATE BAY TYPE (DIAGONAL JOINTS)

FIG. 95



ALTERNATE BAY TYPE (STRAIGHT JOINTS)

FIG. 96



CONTINUOUS SLAB TYPE

FIG. 97

simultaneously; therefore, with this type of construction one wheel of the axle traverses the joint before the other wheel.

If the road is to have kerbs on the sides, these are laid first—and are laid on a concrete base which forms haunching. The kerbs, after being laid and aligned, are cement-grout jointed, and concrete is placed at the back—commonly known as "backing-up". This is to enable them to resist side-thrust when, later, the bay concrete is placed and tamped.

The "backing-up" of the kerbs thus prevents their being pushed outwards.

After a suitable length of kerbing has been laid, checked for alignment, backed up, and the backing concrete has

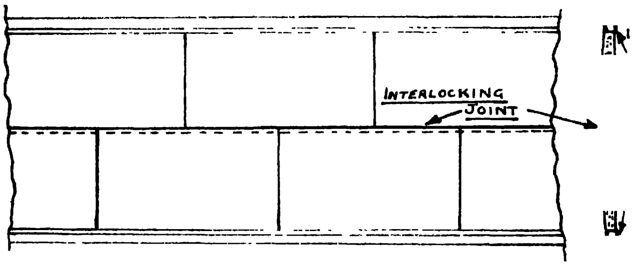


FIG. 98.—STAGGERED BAY (LONGITUDINAL INTERLOCKING CENTRAL JOINT TYPE)

set hard, steel profiles (as shown in Fig. 99) are set diagonally to form the bays, and these profiles are used on which to perform the tamping operations. The profiles (or forms) are set at an angle of approximately 60° from the kerb line, as shown in Fig. 95, and are of heavy rolled-steel channel section curved to provide for the camber of the road.

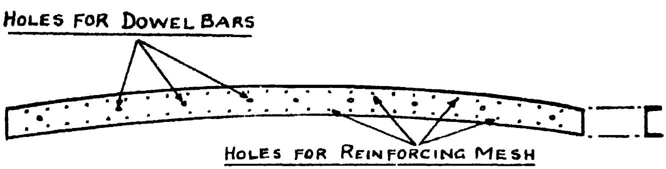


FIG. 99.—STEEL PROFILE, OR FORM FOR CAMBERED ROAD

Incidentally, trunk roads for this type of construction usually have a camber of ¼ in. per foot of width of road (i.e., from the centre of the crown to the inner face of the kerb, in each case). Therefore a 30-ft. wide road has a camber of 3¾ in.

For a 9-ft.-thick concrete road-slab the depth of profile

channel is 9 in. and it has 3-in.-flanges, top and bottom. Since this section weighs approximately 20 lb. per foot, provision must be made to support it and prevent it from sinking into the ground during tamping on its top flange.

For this purpose a trench is dug about 12 in. deep by 6 in. wide, and filled with mass concrete of a fairly stiff mix. The profile is positioned on this concrete, aligned, levelled, greased, and pegged with steel pegs before the concrete finally hardens. As will be seen in Fig. 99, holes are provided in the profile through which can project the longitudinal reinforcement wires for interlocking with the adjacent bay. Holes are also provided, where shown, for

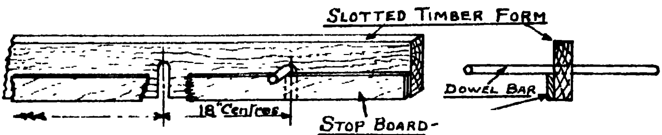


FIG 100—DOWEL BAR SUPPORT

dowel bars, when used for expansion joints similar to those shown in Fig. 100.

Incidentally, these dowel-peg holes are also used by workmen for lifting the profiles into and out of position, by passing steel bars through them.

Since the profiles are heavy, it requires six, eight, or ten men, working in pairs, to handle them, each case depending on the width of road, and therefore the size of profile concerned.

After having set the profiles and positioned the reinforcing mesh, the bay is ready for concreting, but it is customary to set or position sufficient profiles at one operation to suffice for several days' concreting.

Since (as mentioned earlier) bays No. 1, 3, 5, and so on are concreted first, sufficient time must elapse for these to set and harden before their profiles can be removed.

This time—usually three days in the United Kingdom—

depends on climatic conditions and whether ordinary grade Portland cement or rapid-hardening grade is used. The time of three days applies to the ordinary grade.

After removing the profiles from bays No. 1, 3, 5, etc., all that remains to be done to the even-numbered bays—2, 4, 6, etc.—prior to their concreting, is to place the reinforcement mesh and interlock it with the projecting mesh wires of the bays already concreted. Bays No. 1, 3, 5, etc., are usually known as profile bays, and those numbered 2, 4, 6, etc., as intermediate bays. After removing the profiles, the intermediate bays are tamped on the edges of the profile bays.

Convenient lengths for bays are 12, 14, or 15 ft. for manual tamping; bays exceeding these lengths may require power-operated tampers.

The operations of placing and tamping the concrete are similar to those previously described (for floor-slabs, etc.), but for roadworks, instead of finishing the surface by "sweeping", an alternative method is to use a canvas belt 8–12 in. wide. After the tamping has been completed, the belt is placed gently across the work and pulled lightly to and fro, by an operator at each end. During this action the operators also advance longitudinally very slowly.

This operation removes the marks left by the tamper and provides a relatively smooth finish.

On some jobs, in between the tamping and belt-finishing operations, a "smoothing" board or finishing board is used to obliterate the tamping marks and assist in procuring a smooth finish. This board closely resembles a tamper, but instead of being steel shod, it is provided with a strip of teak 6 in. wide by 1 or 1½ in. thick (see Fig. 90*a*).

Fig. 101 shows a series of bays for a small road under construction, but in this case straight (or un-cambered) timber forms or profiles are illustrated, as used for a warehouse floor-slab. Furthermore, no reinforcements are shown.

Usual slab thicknesses for this type of road are 6, 8, 9, and 12 in., depending on the traffic to be encountered.

Suitable concrete mixes are 1 : 2 : 4 or 1 : 1½ : 3, of clean, washed, and well-graded aggregate.

For roads subjected to very heavy industrial traffic the concrete slab may be of two-course construction, by using crushed graded gravel aggregate for the lower course, but crushed graded granite as the aggregate for the upper.

The descriptions so far given apply to roads with kerbing; where no kerbs are to be laid and plain grass verges are to be provided—as in rural areas—steel (or timber) forms must be used to support the edges of the concrete slab.

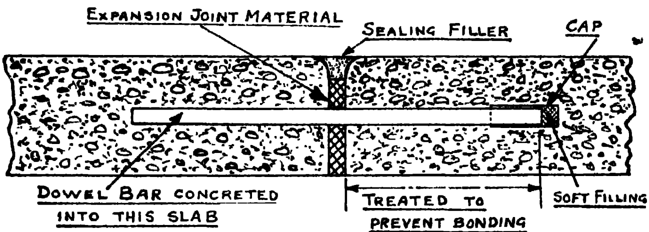


FIG. 100*a*.—DOWEL BAR JOINT FIXING

Typical steel forms for such use are illustrated in Fig. 102. Whichever type is used, the inner surfaces should be greased or oiled by applying the special grades sold for such purpose. Immediately the forms and profiles have been removed they should be cleaned ready for re-use.

Expansion Joints

Several patterns of these are employed, some of which were described and illustrated earlier (Figs. 84, 85, 100, and 100*a*). The distance apart at which these joints should be made depends to a certain extent on climatic conditions in the area concerned, but much controversy exists in regard to this matter. In practice an expansion joint made at each 60 ft. of road length usually gives satisfaction. The distance may be exceeded for alternate-bay-type construction, since each bay, by being cast individually, undergoes

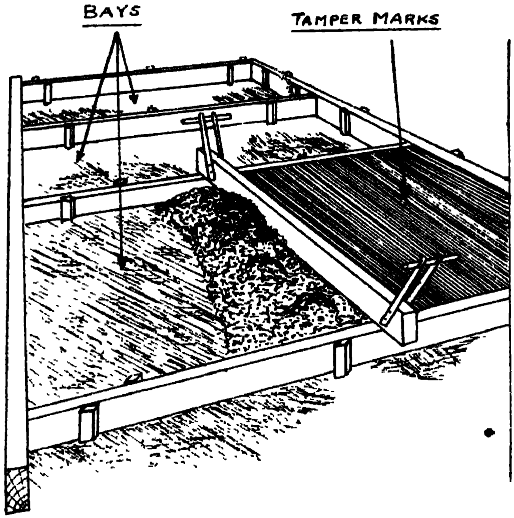


FIG. 101.—CONCRETING AND TAMPING A BAY

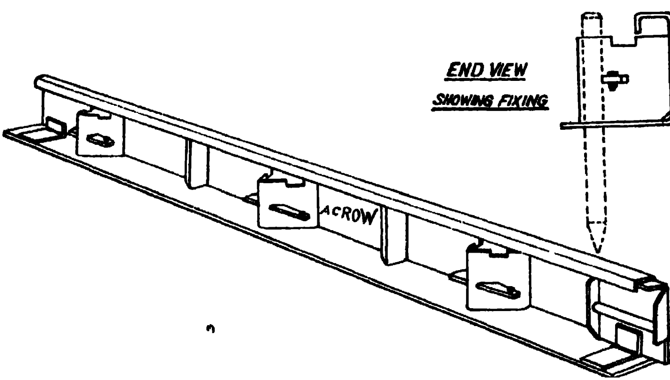


FIG. 102.—STEEL ROAD FORM

(Reproduced by courtesy of Acrow (Engineers), Ltd.)

initial changes before the intermediate bays are added. This practice differs considerably from the casting of one long continuous slab in one operation.

For alternate bay construction, therefore, dowel-bar-type joints may be made at distances of approximately 70–100 ft. The dowel-bars (Fig. 100*a*) are usually of mild steel, $\frac{5}{8}$ in. in diameter by 2 ft. long.

A length of 1 ft. is cast integrally into one slab, and the other 1 ft. length projects from it. Where steel-channel profiles are used with holes provided as shown in Fig. 99, the bars are merely positioned in the holes during concreting but one of the two bays concerned must have the 12-in. lengths of its dowel-bars greased and lapped with greased paper, treated with bitumen, or fitted with cap-ended sleeves into which is placed some soft material of an elastic nature to allow for expansion and contraction.

As an alternative to dowel-bar type joints, those shown in Fig. 84 may be used.

Another well-known expansion jointing material is "Flexcell" (trade term), made by Cellotex, Ltd. This is a specially prepared cellular-type fibre-strip impregnated with bitumen, but in such a manner that the material is of a spongy nature, comprising numerous minute air-cells.

To form the joint, a strip of the Flexcell is placed alongside the edge of a concreted slab, and a small metal protector (or cap) placed at the top.

The adjacent bay (or concrete slab) is then cast and butts up to the Flexcell. After this concrete slab has set and hardened the metal protector is withdrawn and the Flexcell well rammed so as to compact it. In the space thus made at the top by compacting a hot poured sealer—"Pli-astic"—is applied, so as completely to fill the space. This material is an efficient waterproof sealing compound (see Fig. 84*a*).

Incidentally, a similar type of joint to that just described may be formed for concrete airfield runways, but in this case "Aerolastic" is used for the sealer. This is a hot applied compound containing rubber but no bitumen.

For this material it is claimed that it provides exceptional resistance to blast from aircraft jet-type engines and from attack due to fuel spillage. It is resistant to attack by petroleum spirit, kerosene, gas turbine fuel, greases, waxes, etc., which are liable to be spilled on runways.

Another well-known material used for jet-runway joints is "Semguard Grade J", which is a composition of synthetic resin and rubber, etc., and which is unaffected by jet-fuel spillage.

After tamping has been completed, sweeping of the bays may be performed by means of a soft broom, as described earlier.

All that now remains to complete the construction is the curing process—which is similar to that described earlier for floor-slabs—and if desired the bays may be treated with silicate of soda, which provides a "case-hardening" for the surface and prevents it "dusting". A concentrated solution known as P.84 Grade is sold for this purpose.

The silicate-of-soda treatment should follow immediately after the curing process is complete.

Alternate Bay—Type (*b*)

This type of construction is in general similar to that described for (*a*), except that the joints between the bays are at right angles to the kerb-line. The profiles used may be of either steel or timber, but steel is the most satisfactory, since true camber can be maintained.

The bays are tamped longitudinally—i.e. parallel with the kerb-line.

Continuous Slab Construction (*c*)

For this type of construction—as shown in Fig. 97—side-forms of either steel or timber can be used, but in both cases the forms should be set on concrete, since for roads of small width the tamping may be performed *across* the road. Here again steel forms are preferable, since they do not distort or warp, as timber is liable to do.

With the continuous-slab construction a timber form is securely fixed across the road at the starting point, and work proceeds continuously. Towards the end of the day's concreting another timber is placed across the road formation at the predetermined position at which work is to stop.

Expansion joints for this type of construction should be placed at intervals of 60–100 ft. It is often convenient, wherever possible, to arrange these joints at the stopping place of the day's work, but if the road is narrow—say 10 or 18 ft.—the length of a day's concreting may exceed 100 ft.,

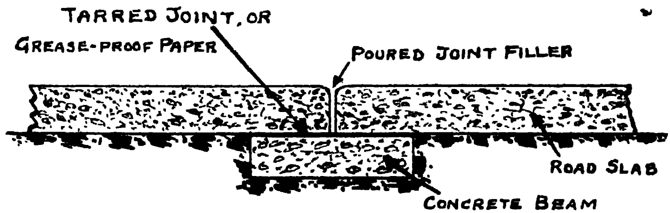


FIG. 103.—CONCRETE BEARER, OR BEAM BELOW A JOINT

in which case an expansion joint should be made at a point not exceeding the 100 ft. mentioned.

Any of the previously described joints may be used, but if the dowel-bar type is to be employed, a slotted timber form complete with stop-boards—as shown in Fig. 100—should be used.

An alternative type of joint is shown in Fig. 103, in which a bearer beam of concrete is formed below the joint.

Either poured filler composition or one of the many bitumastic, asphalt, or rubber-based compositions in sheet form, may be employed. It is usual to allow a joint thickness of $\frac{3}{4}$–1 in. per 100 ft. of slab length.

The operations of concreting and curing, etc., for this construction are similar to those previously described.

Staggered Bay (Central Longitudinal Joint Type) (*d*)

When the width of the road exceeds 30 ft., or it has to be constructed in a town or city where traffic must be maintained along one half of the road, the type shown in Fig. 98 may be used.

With this construction a "tongue-and-grooved" joint is formed along the longitudinal centre line. The joint should be made as shown in Fig. 104, and in Fig. 104*a* the formwork for the joint is shown for a 9-in.-thick concrete slab.

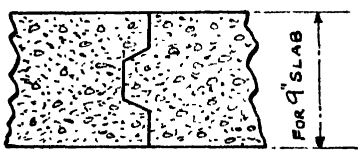


FIG. 104.—LONGITUDINAL T. AND G. JOINT

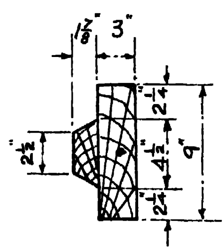


FIG. 104*a*.—FORMWORK FOR T. AND G. JOINT

The road is constructed in two halves lengthways, and may be of the continuous pattern or alternate-bay type, but the former is the more popular.

Expansion joints should be made at distances of 60–100 ft.

The tamping operation is performed across the road, for which a specially shaped tamper must be used—providing HALF the camber of the road.

Steel forms are used for the road edges, after the removal of which kerbs may be laid, or, in certain cases, the kerbs are laid first complete with a rain-water channel, and the steel forms positioned to line-up with the channel edge.

After removing the steel forms, stone sets or concrete can be laid in the spaces originally occupied by the forms.

For forming the T. & G. longitudinal central joint, the

"tongue" section is cast first, and must be suitably protected from damage until the half of the road comprising the "groove" can be cast.

Special Road-Making Plant

In addition to the plant described earlier under the heading of mixers, special appliances are now used extensively

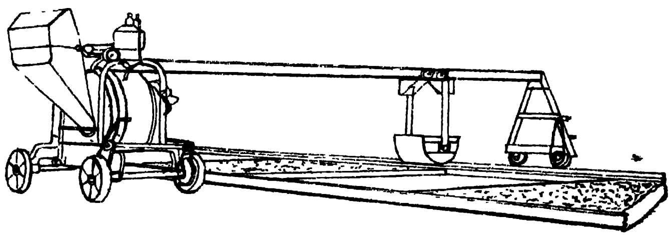


FIG. 105.—MIXING AND DISTRIBUTING PLANT FOR ROADWORKS
(Reproduced by courtesy of Stothert & Pitt, Ltd

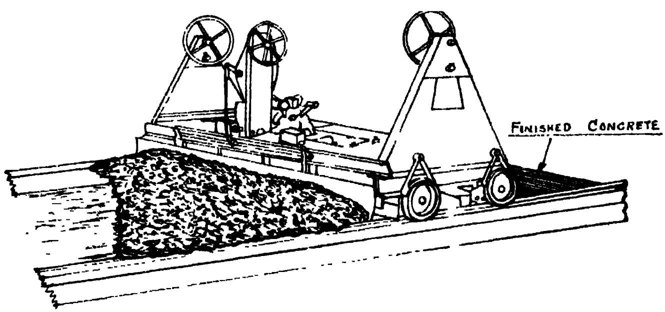


FIG. 106.—CONCRETE ROAD VIBRATOR
(Reproduced by courtesy of Ransomes & Rapier, Ltd

for spreading, levelling, vibrating, and finishing concrete roads, strips, etc.

Fig. 105 shows a mixer equipped with a beam and skip made by Stothert & Pitt, Ltd., whereby the mixed concrete can be deposited into the skip from the mixer and fed to any part of the bay. The plant is so arranged that it

can travel along on either road or rail wheels to suit site conditions.

Fig. 106 depicts a concrete road vibrator and finisher made by Ransomes & Rapier, Ltd.

This machine spreads and levels the concrete and vibrates it so as to completely finish the work. The machine, which is power driven and operated, travels on rails installed at both sides of the road under construction.

Grouted Wheel Tracks

A cheap type of road, suitable for farms, estates, and undeveloped areas, may be constructed by forming what are

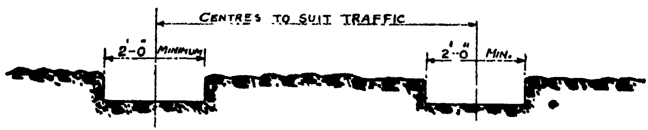


FIG. 107.—EXCAVATION FOR TRACKS

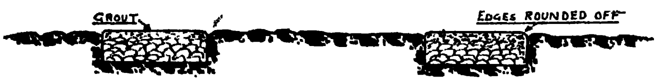


FIG. 107a.—FINISHED TRACKS

termed "grouted tracks", spaced at a distance apart to suit all normal vehicles likely to be concerned.

These tracks can follow the contour of the land, and no special levelling is therefore necessary.

All that is necessary is to peg out the site and stretch lines at the required widths. The soil is then excavated to a depth of 4 in. Broken stone, etc., is then placed in the trenches to within ½ in. or 1 in. of the finished surface.

A cement grout consisting of a 1-cwt. bag of cement, 2½ cu. ft. of sand, and 7 gallons of water is poured on to the large stones and brushed in by using a stiff broom to work the grout around and in between the stones.

If the large stones are very coarse, the grout should

be poured to half their depth, and a layer of $\frac{3}{4}$ in. shingle spread over the surface before grouting up to the top.

Finally the edges of the dual tracks should be trimmed and straightened before the grout hardens.

Fig. 107 shows an outline of the excavation for the dual tracks, and Fig. 107*a* gives a typical cross-section of the completed grouted tracks.

If so desired, however, edge-boards may be used, similar to those shown in Fig. 92, and ordinary concrete can also be used to form the wheel-tracks.

When ordinary concrete is to be used, this may be vibrated by the " pan "-type machine illustrated in Fig. 91*a*.

CHAPTER VII

HEAVY CONCRETE FOUNDATIONS (OR "MASS CONCRETE")

THE term "MASS CONCRETE" is generally applied to heavy foundations which require a large mass or volume, such as "footings" for large buildings.

It applies also to dams, bridge foundations, and those used for supporting heavy industrial machinery, and in most cases refers to plain concrete, as distinguished from reinforced work.

In many instances sea walls, embankments, etc., may be classed as mass work.

For mass concrete the mix used is frequently one whereby "ballast" or "shingle" containing an approximate suitable quantity of sand; that is to say, a mix of 1 to 8, or 1 to 10 might be used instead of, say, a 1 : 2 : 4 or 1 : 3 : 5 mix.

Mass concrete is sometimes used if during the construction a soft area is discovered in the subsoil. This would be excavated and replaced by concrete to form a solid base or foundation upon which to cast the slab proper.

From the foregoing, the reader will realize that in many cases mass concrete is not of the same high grade, or as rich a mix, as that used for other work.

In the majority of cases the term refers to work below ground level, but not always so, since mass concrete may be used to comprise the foundation of some large industrial machine, both below and above ground level—as in the case of the heavy concrete piers which support cement kilns.

Mass concrete employed for heavy foundations—bases for buildings, floors, etc.—is frequently deposited by long chutes direct from one or more mixers, the position and

inclination of the chute being varied to deliver to large areas as the work proceeds.

In all cases the mix, water–cement ratio and workability depend on the nature of the job. For mass concrete it is just as important to maintain a correct water–cement ratio as in the case of other work, and to consolidate it well if good results are to be obtained.

It is erroneous to regard mass concrete as just a sloppy mixture deposited more or less to fill a space. In fact mass concrete for the foundations of heavy steel columns—as used in steel-framed buildings—is a very important item which requires good-quality concrete, well compacted to enable a dense solid mass to be formed suitable for carrying the heavy loads which the steel columns are often called upon to support, without causing settlement, etc.

The reader will appreciate this factor for columns or stanchions, which carry heavy overhead travelling cranes in a building. For the construction of such foundations certain precautions have to be taken whereby the foundation bolts—placed in the concrete foundation to secure the steel columns—can be adjusted during the final levelling and aligning of the column's steel bases.

This is sometimes accomplished by forming pockets in the concrete for the bolts. In order to do this, timber boxes of square cross-section are placed vertically at the required positions during the casting of the concrete. In order to provide vertical adjustment for the column steel bases, the concrete foundation is left "low" and grouted up finally after the steel bases have been aligned and checked.

The timber boxes (which act as templates) are withdrawn after the concrete has set and hardened; the steel bases and foundation bolts are placed in position and steel wedges are used on which to support the steel columns during their alignment and levelling (see Fig. 108).

This allows the bolts to be suspended from the steel bases and thus provides for both vertical and lateral movement during the levelling.

It is therefore customary to leave the concrete foundation 1 in. or 1½ in. lower than the finished level until the steel bases have been checked.

After the spaces have been "grouted-up" by pouring in

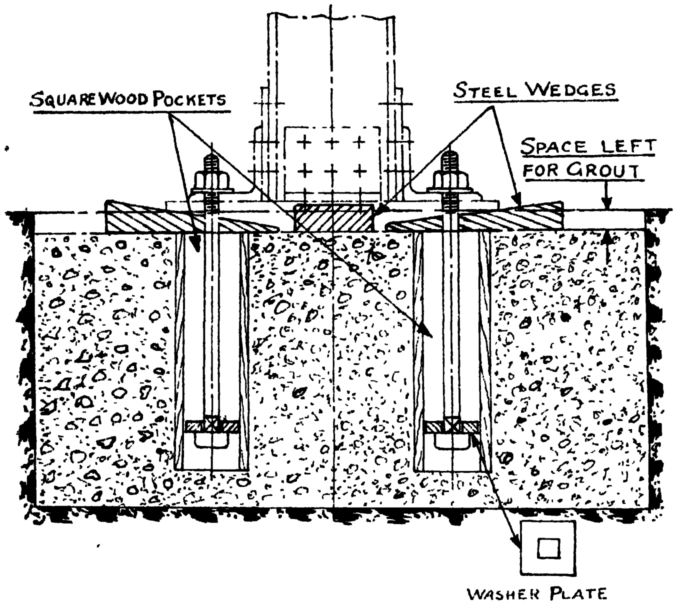


FIG. 108.—CONCRETE LEFT LOW FOR GROUTING

liquid grout and after this has hardened, the steel wedges can be withdrawn and their spaces grouted up.

As an alternative to using timber boxes, certain proprietary devices are on the market which comprise special foundation bolts, with spreaders and tubes.

For mass concrete employed in heavy dam construction, large blocks of roughly hewn solid stone or rock, known as "plums" or displacers, are often placed, or set in concrete. In some cases these plums may weigh up to several tons

(each) on a large job. Their purpose is dual: first, to economize on the concrete, and secondly, to form pillars or "bonds" to hold the mass together.

Plums should therefore be placed so as to enable the wet concrete (during its casting) to surround them, in order to form an effective bond. A certain amount of skill is required in the spacing and placing of plums; this can be acquired only by experience.

Plums are often used with success in sea-wall defence works exposed to severe storms, since they prove very effective if, due to wear and tear, hollows are washed in the concrete surface; the plums assist in resisting complete disintegration until the storms abate and repairs can be effected.

Large foundations of a heavy and deep nature cannot be completed in one operation, and must be constructed in "courses" or layers. It is advisable, therefore, not to finish a coarse off level, but to leave it rugged or irregular, also to leave the surface rough or jagged when finishing the day's work or the "shift".

Next day, or when work is re-started, the surface, which will have set and partly hardened, should be damped or watered before placing furtl. r fresh concrete. In some cases a thin sprinkling of liquid grout is given prior to applying fresh concrete, in order to obtain a better bond. Although this may be so in specific cases, in others the grout may be the cause of cracks developing later, especially where it has been of a rich nature.

CHAPTER VIII

PRE-CAST UNITS, ETC.

General

Under this heading various concrete articles of plain and reinforced types may be classified, such as concrete blocks, paving-slabs, kerbs, fence-posts, garden gate-posts roof-beams, railway sleepers, etc.

These are made in moulds, and for small jobs may be hand rammed, but for mass-production special machines are employed, most of which incorporate various vibration methods in order to effect good consolidation.

In all cases the mix used should be as dry as possible, consistent with suitable placing and workability.

Small but well-graded aggregates are used, some of which may be coloured to provide attractive finishes. In some cases coke-breeze or clinker is used, especially for making blocks for partition walls.

Where reinforcements are used, these must be effectively secured, so as to avoid displacement during the vibration process.

In the moulding process it is also possible to use a special aggregate for the "facing" mix and one of cheaper or coarser grade for the filler or backing mix—as in the case of paving-slabs, tiles, etc. Granite chippings are often used for this purpose.

In all cases, however, it is essential to grease or oil the inner faces of the moulds—as described in earlier chapters.

Concrete-Block Manufacture

These are made by pouring ready-mixed concrete into pre-shaped moulds, vibrating, and pressing them so as to

drive out surplus moisture and to consolidate the mix. The blocks shown in Fig. 109 may be of either hollow or solid formation. In order to make the hollow type (shown dotted), blocks of wood or metal are secured in the desired positions in the mould.

Fig. 110 illustrates an interlocking pre-cast block. Coke-breeze is sometimes used in the manufacture of these, especially when they are intended for partition-wall use.

For mass production, various types of automatic presses

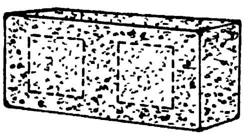


FIG. 109.—CONCRETE BLOCK

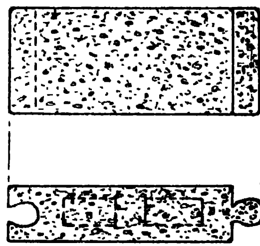


FIG. 110 INTERLOCKING BLOCK

are employed, or, as an alternative, the separate moulds are placed on a vibrating table, similar to those shown in Figs. 111 and 112, which illustrate the " Sinex " and the " Vibrelec ", respectively.

In addition to those illustrated, many other types and sizes of blocks can be made merely by using moulds of other shapes. Cement floor-tiles are also made in various sizes by using a mixture of fine aggregate, sand, and cement, to which colouring matter is frequently added. A typical cement tile is shown in Fig. 113.

Roller " pan-type " mixers are commonly used for mixing the materials for block and tile manufacture, and for making mortar, etc.

These differ from the drum-type mixers considered in earlier chapters, since the aggregates used are of a finer or

smaller character, and it is claimed that the materials do not "ball-up" in the pan mixers. Fig. 114 shows the "Rol-

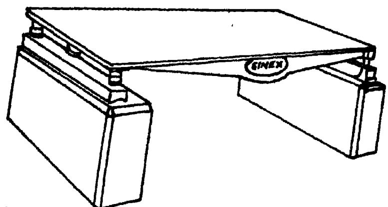


Fig. 111.—Sinex Vibrating Table (Electrically Operated)

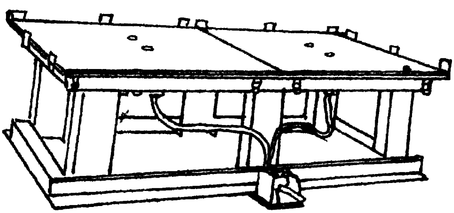


Fig. 112.—Vibrelec Vibrating Table
(Reproduced by courtesy of the Liner Concrete Machinery Co., Ltd.)

Fig. 113.—Cement Tile

panit" mixer—made by the Liner Concrete Machinery Co., Ltd.

These machines are made in various sizes, ranging from 3 ft. 6 in.-diameter pan, having an approximate output per batch of 5 cu. ft., up to 5 ft. 6 in.-diameter pan with an output of approximately 12 cu. ft. per batch, when mixing

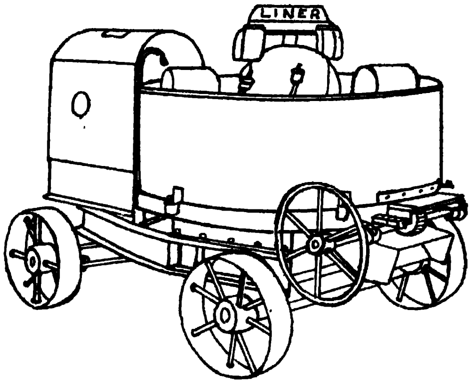


FIG. 114.—LINER ROLLER-PAN MIXER
(Reproduced by courtesy of Liner Concrete Machinery Co., Ltd.)

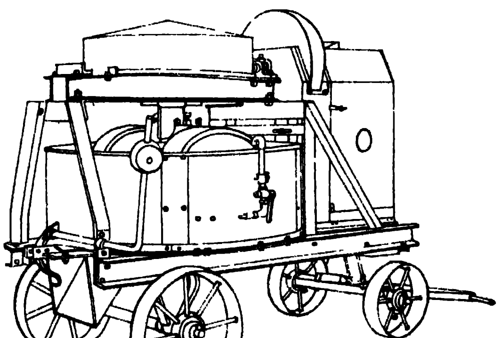


FIG. 115.—OVEROLL PAN MIXER
(Reproduced by courtesy of Frederick Parker, Ltd.)

sand-lime mortar. The outputs vary according to the materials used for the mix and its consistency.

Another well-known pan-type mixer is the "Overoll" (made by Frederick Parker Ltd.), shown in Fig. 115.

These are made in sizes of 4 ft. 6 in. and 5 ft. 6 in. pan diamaters, and are available driven by petrol or diesel engines, or by electric motors. These machines are used extensively for the mixes of block-making plants.

The machines used, as distinct from plain vibrating tables

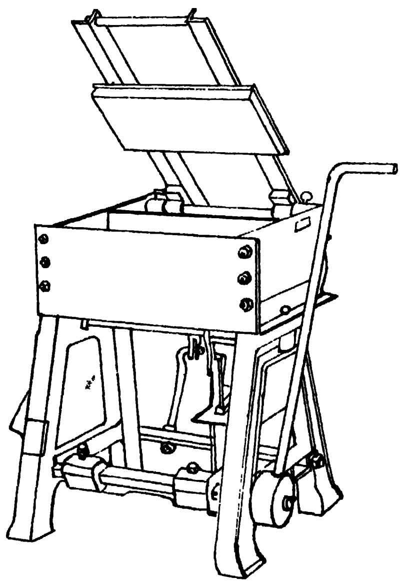


FIG. 116.—COMBINATION CONCRETE BLOCK, SLAB AND BRICK-MAKING MACHINE

(Reproduced by courtesy of Winget, Ltd.)

on which small moulds are compacted, are of the press or tamp type.

Fig. 116 shows a typical block or slab-making machine, and an adaptation of this pattern is also used for concrete-brick manufacture, and is capable of making four bricks at one operation, merely by changing over the accessories. The machine illustrated is the tamper-plate type, and

the tamping is performed by manipulating the handle at the side, which operates the spring-loaded tamper-plate.

The mix is placed on a pallet in the machine, and after

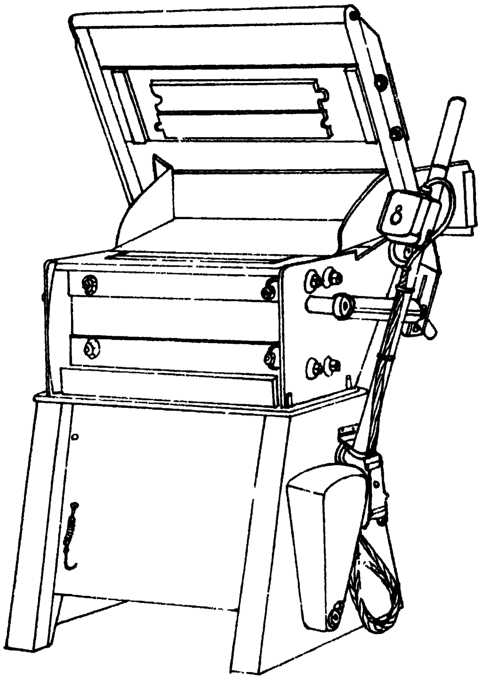


FIG. 117.—ELECTRICALLY VIBRATED BLOCK AND SLAB MACHINE

(Reproduced by courtesy of Winget, Ltd.)

being tamped is removed from the machine and stacked on the pallet for final drying out and curing, etc. An output of sixty to seventy slabs per hour is possible with this machine.

In addition to the manually operated tamping machines,

those of the electrically vibrated type are used for slab and block manufacture, and for making concrete bricks—several at one operation. A typical machine is shown in Fig. 117 and is capable of making blocks of several varieties merely by changing the equipment; both solid and hollow blocks up to 24 in. by 9 in. by 9 in. in size can be made in it.

The machine shown in Fig. 118 is capable of making

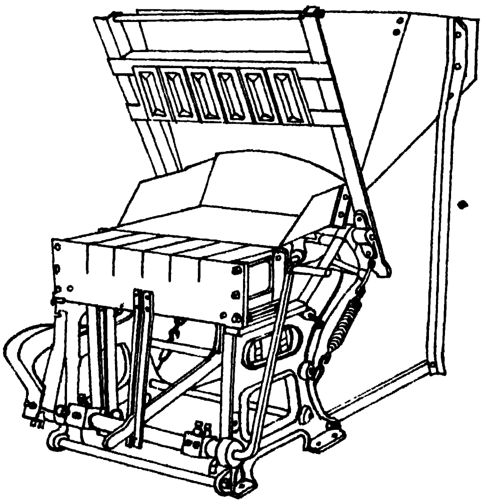


FIG. 118.—SIX-BRICK-MAKING MACHINE

(Reproduced by courtesy of the Liner Concrete Machinery Co., Ltd.)

bricks in breeze, clinker, sand, and gravel, etc. It makes six bricks at one operation, and no hand-tamping is required, since the tamper plates actually enter the box.

By an upward movement of the operating lever, all the division plates are withdrawn through the back of the box in one operation. The average time required to complete one cycle of operations for the manufacture of the six bricks is thirty seconds.

Fig. 119 illustrates a "Winget" rotary hydraulic block-making machine—specially suitable for the manufacture of stabilized soil blocks.

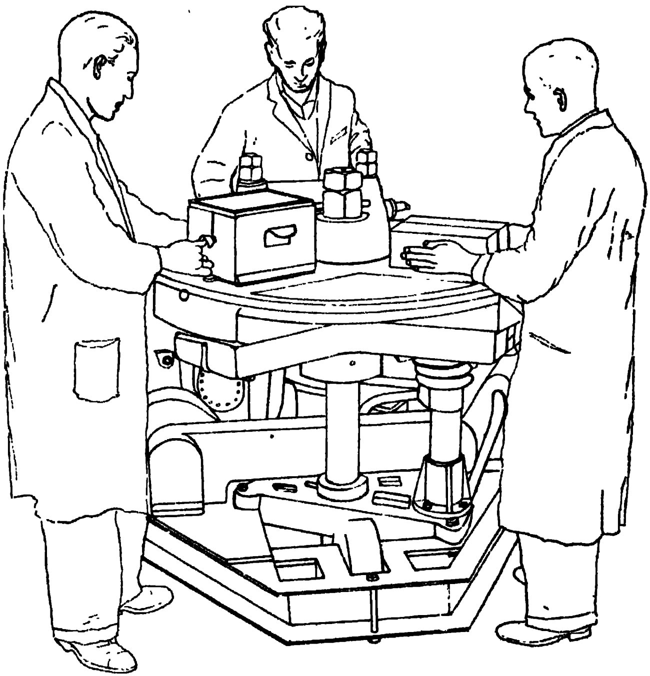


FIG. 119.—WINGET ROTARY HYDRAULIC BLOCK-MAKING MACHINE

Experiments have proved that any soil containing the correct proportion of sand and not less than 18 per cent. of clay is made suitable for stabilization by adding between 2½ and 5 per cent. of cement. For efficient mixing, however, a trough-type mixing machine (see Fig. 120) is recommended.

A standard machine makes a block 12 in. by 6 in. by 4 in. either plain or with grooves top and bottom (i.e. on the 12 in. by 6 in. faces). It can also be supplied to make 11 in. by 9 in. by 4 in. blocks, with male and female grooves both on the face and ends.

The machine embodies hydraulic pressing with hydraulic ejection around a rotary mould-table. The power to drive the hydraulic pump is supplied by a 1·9-h.p. petrol engine—or an electric motor can be supplied.

The mould-table incorporates three mould-boxes. There are thus three operating positions—filling, pressing, and

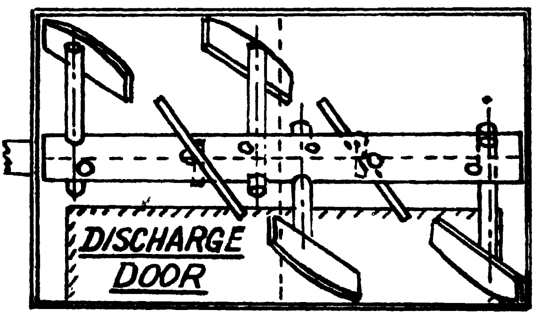


FIG. 120.—WINGET TROUGH MIXER (SHOWING PADDLES)

ejecting. The pressing ram goes to a definite stop, thereby ensuring that all the blocks are of a constant thickness. Two levers control the operation of the machine: one to raise and lower the rams, and one for the mould-location stop. They are interconnected for safety in such a manner that the rams cannot be used until the table-top is in position, nor can the stop be withdrawn unless the rams are retracted.

A load of up to 45 tons is applied by the pressing ram; when the maximum pressure is attained a "tell-

tale" rises, thus giving the operator the signal to retract the rams.

The machine is supplied with two adjustable volume screed-boxes, which are used in preference to weighing. Accurate filling of these boxes is a simple operation which ensures constant compaction and requires no special skill on the part of the operator.

Three operations take place at the same time, the sequence of which is as follows :—

One man fills the machine mould-box with the material, using the screed-boxes supplied, and inserts the top pallet. The table is then moved one third of a turn and engages in the " stop " provided.

The second box is then filled in the same way, and pressure is applied to the first block, which is now in the pressing position. The ram is retracted and the table moved a further third of a turn. The empty box is filled again, and the operator presses the previous block. At the same time, the ram ejects the first block, which is then carried away for stacking or used direct on the job.

The sequence now becomes constant, and means that the production time of a block is equal to the longest operation involved—i.e., the operation at the pressing station, which occupies approximately twenty seconds.

By using ready-mixed materials and four operators, 140 true-size blocks can be made per hour.

Incidentally, cement tiles, as shown in Fig. 113, are manufactured on a somewhat similar rotary table machine to that just described, and operated hydraulically to obtain the pressing and ejection. In many cases the tiles may be given an attractive finish on the face side by using special facing mixtures containing coloured materials. After pressing, however, and when thoroughly set and hardened, the tile-faces are ground and polished, thereby exposing the special aggregates. Fine marble chippings are frequently used in the mix to produce these attractive finishes.

Fence-Post Manufacture

Concrete fence-posts, gate-posts, etc., can be made in suitable moulds and the mixture vibrated to effect good consolidation.

The posts, however, must be reinforced in order to stand up to the duty called upon. Fig. 121 shows a typical post suitably reinforced by steel rods near each corner position.

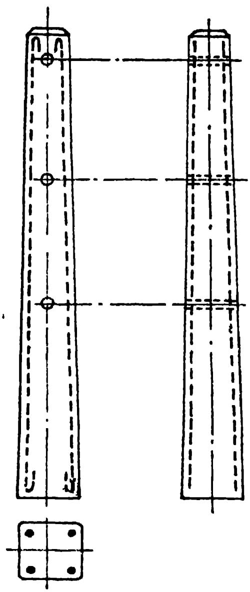


FIG. 121.—CONCRETE FENCE-POST

Posts vary in size, and may be 4–6 in. square at the base, with suitable taper towards the top.

The type illustrated is such as is used for field fencing, railway embankments, etc. For larger sizes, the vertical steel reinforcements are sometimes fitted with links at about 6-in. pitch and similar to those shown for the concrete

column in Fig. 69. In order to form holes in the posts for wires, eye-bolts, etc., wood pegs are positioned in the moulds prior to casting the concrete, or short lengths of steel tube can be cast in. It is essential that the inner faces of the moulds and the surfaces of the wood pegs are greased or oiled to prevent adhesion.

The concrete used must be a dry mix and thoroughly well vibrated, or tamped, to procure a dense mass.

Municipal electric-light standards are made in reinforced concrete on similar lines to those described for fence-posts.

These call for very careful handling after being extracted from the moulds, and should be lifted in slings—spaced at suitable distances along the length—or breakage may result.

Railway Track Sleepers

These are now made in reinforced concrete, and are rapidly superseding timber sleepers. The sleepers are cast in moulds and vibrated until the required density has been attained.

Concrete Piles

In soft ground, or that having low load-bearing properties, timber piles were formerly driven in to support the loads. These have now been superseded by reinforced-concrete piles, on account of their numerous advantages.

For small jobs pre-cast concrete piles may be of 10 in. by 10 in. cross-section and with suitable steel reinforcements; however, piles of 12 in. by 12 in., 15 in. by 15 in., and 18 in. by 18 in. cross-section are now used extensively. Moreover, reinforced-concrete piles of 24 in. by 24 in. cross-section have been successfully driven over 110 ft. in length (see Fig. 122).

When a piled foundation is necessary, the ultimate load which a pile of any size will carry may be calculated from one of many formulæ. This load depends on the weight of the hammer (or "monkey") and its height of fall, the weight of the pile, and the "set" or average distance

through which the pile sinks under each of the last five or ten blows from the hammer during driving.

The piles have pointed steel shoes cast integrally into their penetrating ends.

Piles may carry their load either entirely on the shoe, acting as a column, by lateral friction between the pile surface and the surrounding ground, or by a combination of these two actions. The reinforcement must therefore be designed so that the pile may act as a column at points where it is unsupported and will not crack when being lifted to the pile-driving frame.

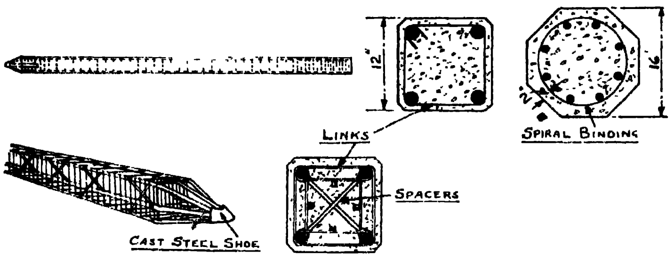


FIG. 122.—TYPICAL SECTION CONCRETE PILES

Piles are usually made in a box-like frame—called a " pile-bed ". They are cast horizontally in the bed, which is so partitioned that ten or twelve piles can be made at a time.

The reinforcement is carefully placed in position and firmly secured. When the concrete is poured into the bed, vibrators are placed to the shuttering and set in motion so as to produce a dense, compact concrete.

The shuttering must be of robust construction and suitably braced together in order to prevent any possibility of warping.

After casting, the piles must be suitably cured for several days before taking them from the shutters.

The mix generally used is 1 : 1½ : 3, but satisfactory piles for small jobs have been made from 1 : 2 : 4 mixes. The

cover for the main reinforcing bars should not be less than 1½ in., and 2 in. for large piles.

When using ordinary grade Portland cement for concrete-pile construction, the piles should never be driven until they are at least one month old, but with rapid-hardening cement this period may be reduced by about 50 per cent.

Reinforced-concrete piles are generally driven with a heavy hammer and a small "fall". A semi-automatic hammer giving forty blows per minute and weighing 2½ to 5 tons is suitable.

Square piles are generally reinforced with four or eight longitudinal steel bars and bound with ⅛-in., $\frac{3}{16}$-in., or ¼-in. rods (called "stirrups", or links) at suitable spaces. The stirrups are secured to the longitudinal bars by "binding wire".

Octagonal piles usually have eight longitudinal bars, and are wound with a helical steel wire instead of stirrups.

Pre-cast reinforced-concrete piles are fitted with shoes of cast steel or wrought iron with diamond-shaped points. The stirrups should be spaced more closely near the shoe-end and at the top of the pile, as shown in Fig. 122, and must be securely tied with soft iron binding wire.

"In Situ" Concrete Piles

In addition to the pre-cast reinforced concrete piles just described, piles may also be cast "in situ".

There are three methods adopted for the construction of the latter :—

(*a*) Driving into the ground a double steel shell; the inner one being then withdrawn while the outer shell is filled with concrete, after first closing its base.

(*b*) Driving a single steel tube with a steel or concrete point and withdrawing the tube slowly, while at the same time filling the space with concrete.

(*c*) Driving a screwed steel tube (or mandrel) covered

with a pre-cast concrete casing put on in 2-ft.-long segments, as driving progresses, unscrewing the steel mandrel and filling the pre-cast shell with concrete—either plain or reinforced.

Concrete piles are used extensively for dock construction, on river-bank sites, and river bridges, etc.

Incidentally, Liverpool Dock sheds are formed on piled foundations, and the famous Ford factory at Dagenham was constructed on reinforced-concrete piled foundations; many large power-stations are also constructed on similar foundations.

Concrete Road Kerbs

Kerbs for roadworks are now made in concrete, and are rapidly superseding those of granite, since the former are much cheaper, although not so durable.

A common size for concrete kerbs is 10 in. by 5 in. by 3 ft. long, with a chamfered face. They are made in moulds and vibrated to effect consolidation.

For good-class work the faces of the kerbs are granolithic (i.e., made of granite concrete), with gravel concrete used as a filler. It is important to provide a good clean face and top for kerbs, in order to obviate the possibility of rain collecting in any pores, which during frost will some-

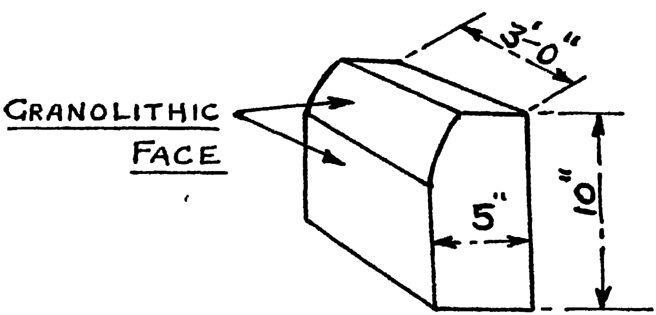


FIG 123.—CONCRETE ROAD KERB

times cause the face to disintegrate. A typical kerb is shown in Fig. 123.

Pre-Cast Concrete Floor (or Roof) Beams

Many types of these exist and have been successfully used, especially in recent years, due no doubt to some extent to the timber and steel shortages. Moreover, where pre-cast well-matured units can be employed instead of mass concrete floors, there is a considerable saving in time, since the former can be put into full use much earlier.

The foregoing considerations are quite apart from the fireproof qualities claimed for concrete.

When these units are used for roofs, their joints are usually grouted, and the whole surface area is then covered with a thin coating of concrete, which, after setting and hardening, is rendered waterproof by applying a final coating of bitumastic felt, asphalt, Ruberoid, etc.

If the units are used for floors, however, they can be given a floated concrete finish, or floor-boards may be used.

Pre-cast beams can be made in various sizes to suit floor-loads over different spans. The beams are usually cast in moulds and vibrated to effect consolidation. Reinforcements are also included, and provision can be made for continuity over intermediate supports.

"Rapid" Floor-Beams

Among these pre-cast units is the well-known "RAPID" type—of which a typical cross-section is shown in Fig. 124, and from which it will be seen that both top and bottom steel reinforcements are secured at suitable spacings by links.

Fig. 125 shows the arrangement of the beams for typical floor (or roof) construction, from which it will be noticed that the spaces between the interlocking top flanges are finally grouted, or filled in with concrete during the placing of the concrete finish surface.

LINKS- STEEL REINFORCING BARS

FIG. 124.—" RAPID " PRE-CAST FLOOR BEAM

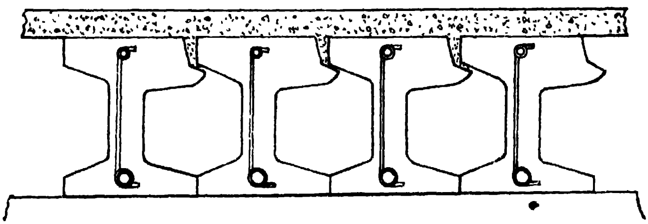


FIG. 125.—TYPICAL " RAPID " FLOOR CONSTRUCTION

" Armocrete " Pre-Cast Floor or Roof

Another well-known type of pre-cast unit floor construction is the " Armocrete ".

This, however, is not an " I " beam type, since the " webs " are independent units, as will be seen in Fig. 126.

Lightweight pre-cast hollow concrete tubes, as shown in Fig. 127, are placed in between two webs, and rest on ledges cast integrally in the lower part of the web—which has steel reinforcement fixed longitudinally.

After fixing the units in position (i.e., webs and tubes), a

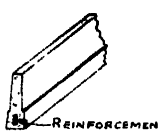


FIG. 126.—PRE-CAST WEB

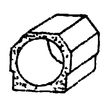


FIG. 127.—PRE-CAST TUBE UNIT

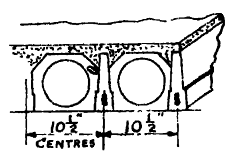


FIG. 128.—" ARMOCRETE " FLOOR CONSTRUCTION

FIG. 129

Table Showing Economical Depths of "Armocrete" Units for Various Spans and Loading

(Loads in lb. per foot supl.)

Purpose.	Super Load.	8 ft.		9 ft.		10 ft.		11 ft		12 ft.		13 ft.		14 ft.		15 ft.	
		ft.	in.	ft	in	ft.	in.	ft.	in.	ft.	in.	ft.	in	ft.	in.	ft.	in.
Roof	30	5	6	5	6	5	6	5	6½	5	7	6	7	6	7	7	8½
Floors:																	
Domestic	30	5	6	5	6	5	6	5	6½	5	7	6	7	6	7	7	8½
Wards	40	5	6	5	6	5	6	5	6	5	7	6	7	6	7	7	8
Offices	50	5	6	5	6	5	6	5	6	5	7	6	7	6	7	7	8½
Classrooms	60	5	6	5	6	5	6	5	6½	5	7	6	7½	7	8	7	8
Banking Hall	70	5	6	5	6	5	6	5	7	5	7	6	7	7	8	7	8
Shops and garages for light cars	80	5	6	5	6	5	6	6	7½	6	7	6	7	7	8	7	8½
Ballroom	100	5	7	5	7	5	7	6	7	6	7	6	7½	7	8	8	9½
Light storage	150	5	7	6	7½	6	7½	6	7½	6	7½	7	9	8	9½		
Warehouse	200	6	7½	6	7½	6	7½	6	8	8	9½	8	9½	Special			

The above table shows the depth of the unit and the overall depth, e g., 6 ft. 7½ in. is a 6 in. unit with a 1½ in. structural screed, and allows for the dead weight of the "Armocrete" floor and 12 lb. for additional finishes.

Full details regarding the above table, together with details of special loadings, are available on application.

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thin layer of concrete is placed as "topping", and screeded level, as shown in Fig. 128.

The hollow tube units, which are made in short lengths for convenience and to facilitate erection, thus provide an arch effect, thereby transmitting the load on to the webs. The spaces between the tops of webs and tubes are concreted in during the casting of the final "surface-finish" concrete, which is usually 1½ in. or 2 in. thick, as required.

When desired, timber floor-boards or other types of surface finish may be incorporated with the final concrete surface. Fig. 129 gives a table of loading for Armocrete flooring for various spans.

CHAPTER IX

CONCRETE PIPES (PRE-CAST)

PIPES (or tubes) are made in concrete, especially when asbestos is mixed with the concrete. The latter are called asbestos-cement pipes.

Concrete pipes are used for the conveyance of water and sewage, and special porous concrete pipes are frequently employed in sub-soil drainage schemes. Asbestos-cement pipes are used extensively both in gas engineering and waterworks.

Cement concrete tubes are also used for electric cable ducting.

Small-size pipes, of up to 12 in. diameter are usually made of plain cement concrete or asbestos cement, but larger sizes are reinforced, especially for resisting external pressure when placed below ground.

The strength of an unreinforced pipe depends on the quality and thickness of the concrete, together with the workmanship.

Tamping is usually performed by special machines, and a fairly dry mix is used. A popular mix for this class of work is 1 part of Portland cement, $1\frac{1}{3}$ parts of sand, and $2\frac{2}{3}$ parts of crushed granite or "whinstone", and the material is vibrated while being deposited.

Tamping machines for concrete pipes generally comprise a rotating table with fixed mechanical rammers, on which a vertical steel mould is placed (or a fixed table with rotating rammers).

Concrete of a fairly dry consistency is fed to the mould in thin layers at a uniform rate and evenly consolidated.

Sockets are usually formed by a special cast-iron ring

attachment, at the base of the mould. A good spigot may be made by driving a cast-iron ring down between the outer mould and the core and then removing the ring.

Rotary Compression

There are two general types of machines used for this process; in both types a fixed internal core is replaced by a rotating cylinder or piston. The mould (fitted with a socket ring) is placed on the machine and the piston lowered into the mould.

In the earlier machines the piston is slightly longer than the pipe to be made.

Concrete is fed on to the revolving piston and tamped down between it and the outside mould, the piston being withdrawn on completion of the filling.

In the latter type of machine the piston, which is fitted with special knives, starts at the base, and as it rotates compresses the concrete in the mould. When the concrete is consolidated sufficiently, the pressure exerted by the knives is enough to lift a portion of the piston weight, the rest being taken by a counterbalance; thus, as concrete is fed in, the piston gradually rises until it reaches the top of the mould.

The completed tube is then removed from the machine and cured.

Pipes made by the rotary compressed method are generally truly cylindrical and well-polished internally.

Vibration Method

In the case of vibrated pipes, the steel or cast-iron moulds are generally placed horizontally on a large vibrating table (similar to that used for making fine pre-cast concrete products) and filled through a longitudinal opening running the whole length of the mould, so as to consolidate the concrete into a dense mass with a smooth finish. It can thus be definitely assured that the joints are truly circular, uniform in cross section, and square to the axis of the pipe.

The spigots and sockets can be cast in one operation and homogeneous with the barrel of the pipe.

Vibrated concrete products, either plain or reinforced, can be of almost any form, and not necessarily cylindrical; the process is suitable therefore for oval, egg-shaped, square, or other shapes of pipes, bends, channels, etc.

Centrifugal Packing

This is a later process, initiated first in the U.S.A., and now developed in England.

The process consists of packing concrete centrifugally, by means of a rising head, against the inside of a stationary vertical steel mould.

While the concrete is being automatically fed into the mould, the shaft and head rotate at approximately 250 revolutions per minute.

The centrifugal force thus created flings the wet concrete rapidly on to the inside of the mould, where it is picked up and packed by the revolving wings (or paddles) on the shaft-head, thereby giving density to the pipe. The steel mandrel trues up and polishes the bore. An auxiliary packer forms the socket in one operation with the pipe, which may have a one-piece reinforcing cage.

Concrete pipes can be made by this process with any type of joint. " Specials ", such as junctions, are made by inserting " stubs " into holes cut in ' green " pipes after both have been cured.

Standard machines can be adapted for making extra thick culvert pipes, or stubs for junctions: but special machines are required for making bends.

A single machine can produce from 25 tons of 6-inch pipes to 100 tons of 24-inch pipes per day.

Centrifugal Spinning

Centrifugal spinning of concrete is now used all over the world for water-supply systems, sewers, culverts, drainage, irrigation, etc. The pipe-spinning machine con-

sists of a set of live rollers, on which the pipe-moulds are placed horizontally.

When these external moulds have attained a suitable speed, the ready mixed cement concrete is inserted from *both* ends of the mould, thus forming an even and compact layer of concrete up to the level of the end-rings of the mould. The concrete is automatically consolidated by centrifugal force; all surplus cement, water, and any foreign matter, as well as air, is squeezed out to the inside and run off. The inside is finally gauged and polished by means of a steel bar.

The complete process occupies from two to three minutes.

Centrifugal concrete, properly spun, is very hard and dense, and therefore extremely resistant to attrition, free from voids, and practically non-porous, even under high hydraulic pressures.

Spun pipes are manufactured to British Standard Specification (No. 556 of 1945).

Spinning is also utilized for the manufacture of lamp-posts, electric traction, power, and telegraph poles in concrete.

It is also used to provide cast-iron and steel pipes with a thin lining of concrete.

Centrifugal Spinning and Concussion

This method combines the advantages of spinning with those of very low frequency vibration. It is claimed that the process provides an even distribution of the aggregates throughout the pipe wall, allows the use of semi-dry and "lean" mixtures, and thus provides a dense and almost impervious pipe, giving a high strength, resistance to attrition, and chemical attack.

General

Concrete pipes generally are pre-cast, manufactured, and matured at the makers' works, but on large contracts, pipes

have been made successfully by special plant installed at the site where they were to be laid.

Pre-cast reinforced-concrete pipes are made, and used extensively up to 6 ft. inside diameter. In the U.S.A. they have been used successfully up to 12 ft. long and 12 ft. internal diameter, but such sizes call for special handling equipment, especially for placing and jointing.

Jointing and Laying

Various methods are used for small- and medium-sized concrete pipe-joints.

The chief essential is to have ample room to get round, especially underneath the joint—where it is generally weakest. Jointing holes, however, must not be dug out so large as to weaken the bearing surface under the pipe barrel (see Fig. 130).

Water should preferably be kept down below the joints until these have set.

Normally, pipes are always laid against the natural

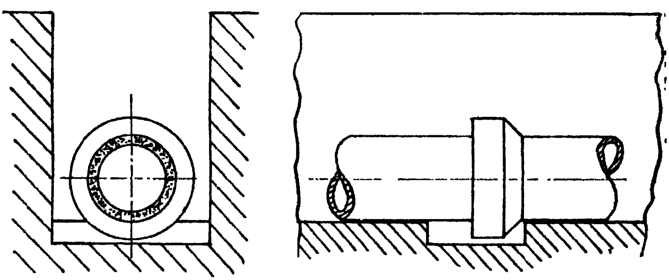

FIG. 130.—HOLE IN GROUND FOR SOCKET JOINT MAKING

direction of flow—i.e., with their sockets uphill. Thus the jointing works all the time *away* from any water or sumps.

The "spigots" and "sockets" should be well cleaned and thoroughly soaked with water, but any surplus water must be removed just prior to making the joint.

Each pipe should be "rung" (or sounded) for soundness immediately before laying, and again *after* laying, to ensure that it has not been cracked during its placing in position. A gasket, composed of hemp, twisted jute, or oakum, in one continuous piece for each joint, should be placed round the spigot of the pipe to be laid.

After the spigot has been inserted into the socket of the preceding pipe, and pushed well home, the pipe should be brought to proper line and level at the socket end, and the gasket lightly caulked with suitable tools. The remainder of the open joint should then be carefully filled with mortar (or "compo", as it is often called).

This is a mixture of cement, sand, and water, of such consistency that when "balled" and squeezed in the hand, moisture will just exude. Care must be taken to ensure that the mortar is pushed well into the joint, especially on the underside of the pipe.

Note.—It is inadvisable to use neat Portland cement and water for jointing work, since this gives too rich a mixture and is liable to crack during its setting and drying.

It has been proved by experience that the best mortar for joints is made by using 1 part of Portland cement, to between 1 and 2 parts of clean sharp sand.

With this mortar, if proper protection is given from sun and wind, a thoroughly sound joint can be made, free from cracks and leakage.

The mortar joint is best made with the hands (preferably protected by rubber gloves), and should be lightly and uniformly caulked to the face of the socket, after which it should be bevelled off with a trowel so as to form a liberal and slightly convex fillet (see Fig. 131).

Where the bottom of the excavation is bad, or any possibility of subsidence occurring, a concrete bed is necessary. This bed should have a minimum thickness of 6 in., and should extend the full width of the trench (see Fig. 132).

Moreover, where concrete pipes—especially those of unreinforced type—are laid in shallow trenches over which

traffic will eventually pass, it is essential to form a concrete "surround" to afford protection for the pipe (see Fig. 133).

It is customary to "splay" off the top, or "bevel" it, as shown in the illustration. When this is performed, however, it is essential to ensure that the concrete does not

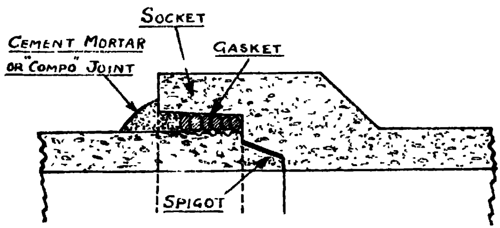

FIG. 131.—SOCKET AND SPIGOT CONCRETE PIPE JOINT

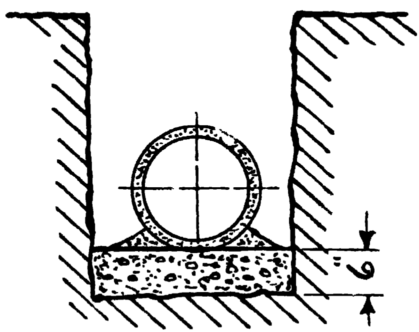

FIG. 132.—CONCRETE BED

slump to less than the minimum 6 in. thickness over the crest of the pipe.

These precautions are especially necessary for pipe culverts under roads, etc., which should always be laid with a concrete surround. If the pipes are of heavy reinforced pattern, the surround may be dispensed with.

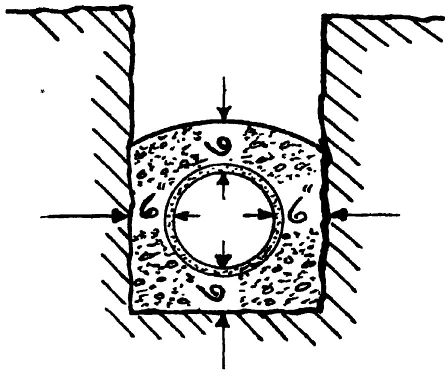

FIG. 133.—CONCRETE SURROUND

Jointing Under Water

Mortar joints should never be made under water if it can possibly be avoided. Where, however, they have to be made in wet conditions the canvas-band method should be used (see Fig. 134).

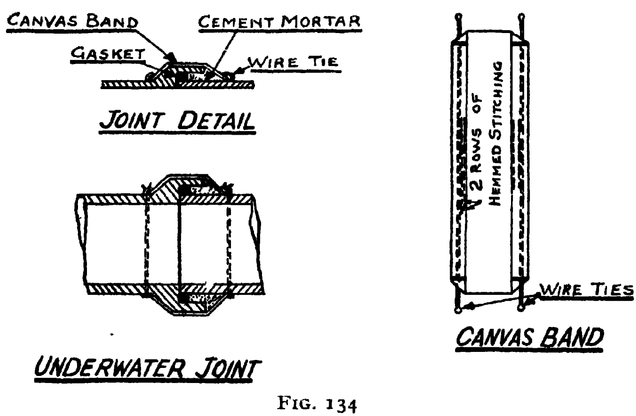

FIG. 134

This comprises a closely woven canvas band, slightly larger than the circumference of the socket of the pipe, and of sufficient width completely to envelop the socket and mortar joint.

A length of pliable wire is inserted inside the hemmed edge and looped at each end for security and fastening. The band may be securely fastened around and at the back of the socket by twisting up one of these wires; this should be done before the pipe is laid.

The joint may then be laid in the usual manner, and the second wire tie fastened round and twisted up. This has the effect of drawing the whole wrapper tightly around the joint, thereby supporting it and preventing water in the trench from washing the cement out of the mortar. In difficult cases both sides of the canvas band may be fastened in position after the gasket has been caulked, and a fairly reliable joint can then be obtained by means of poured grout.

Testing and Back-Filling

If the methods described above are adopted, no special cement is required for sound, water-tight joints, unless early testing and filling-in of the trench are necessary.

Before filling in (or back-filling) is performed, every length of jointed pipe-line should be tested with a specified head of water (or, in special circumstances, with smoke or compressed air).

Due regard must be paid to the back-filling of the trench. This should be performed carefully, in order not to disturb the pipe-line in any way after it has once been laid, jointed, and tested.

It is safest never to walk on the pipe-line after laying and jointing it.

A fine sprinkling of earth should be gradually added down the sides and over the top before earth in bulk is placed.

Note.—This procedure is, of course, unnecessary where a concrete surround has been made.

Ogee Joints

Concrete tubes (or pipes) with "ogee" joints should be jointed with cement mortar (of a mix usually 1 to 1), made into a putty and placed in the lower half of the socket of the tube in position. The upper half of the spigot of the tube to be laid is "buttered" in a similar manner, and the tube is then driven carefully home. After this has been done, the *inside* of the joint is pointed up and a fillet of cement mortar (mix usually 1 cement to 2 of sand), 3 in. wide by 1 in. thick placed around the outside of the joint (see Fig. 135).

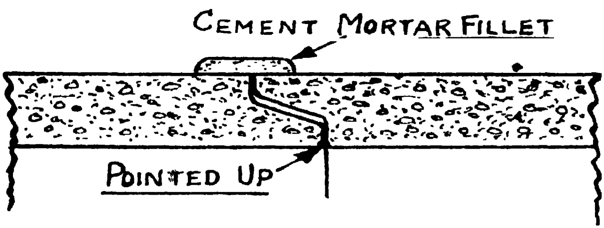

FIG. 135.—OGEE PIPE JOINT

Flexible Joints for Concrete Pipes

In cases where heavy traffic, etc., may cause vibration, it is desirable to provide underground mains with some means of adjusting themselves to slight movements of the sub-soil.

In such circumstances a flexible joint, such as the "Stanton-Cornelius" (trade term), may be used.

This joint remains leak-proof when deflected under a hydraulic pressure of 250 lb. per square inch, or under an air pressure of 75 lb. per square inch. It can be assembled by unskilled labour under certain conditions which would render other types of jointing difficult, for example, under water in confined spaces, or over uneven ground.

The making of this joint requires only a few minutes,

and the saving in laying time, excavation, and materials can be set off against the cost of the pipes.

Flexible-jointed concrete pipes are ideal and very economical for either temporary or permanent pipe-lines and pumping mains carried over the surface of the ground.

The "Stanton-Cornelius" joint is an integral part of the pipe, the only loose member being a ring of special rubber. After the trench has been excavated and prepared, the pipes should be laid loosely in position (spigot to socket), without jointing rings, leaving room for a small motor-car jack and blocks between the first and second pipes to be jointed. The jointing ring is placed on the extreme end

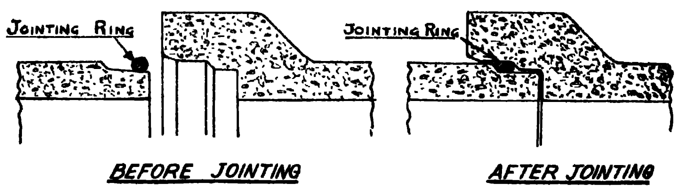

FIG. 136.—STANTON-CORNELIUS CONCRETE PIPE JOINT

of the spigot of the pipe, and the spigot entered into the socket (see Fig. 136).

The blocks and jack are then inserted to force the spigot into the socket, which operation completes the making of the joint. The jack and blocks are then removed and the operation repeated for the remainder of the joints.

If, after the joint has been made, the pipe proves to be high or low when checked for level, adjustment may be made without damage to the joint. When jointing pipes above 15 in. in diameter it is advisable to allow the weight of the pipe to rest on the tackle used for lowering the pipe into the trench. This enables the pipe to be moved forward with greater ease.

Pipes of 24 in. in diameter, or over, are best jointed by a special attachment supplied by the pipe-makers.

Porous Concrete Pipes

For land-drainage purposes, porous concrete pipes are used extensively, and claim advantages over ordinary agricultural land tiles for strength and efficiency.

Porous concrete pipes are made by a special process; the aggregate used varying from hard stone to pumice.

Standard sizes range from 3 to 24 in. internal diameter. Joints are normally left dry, and are usually of rebated or ogee form.

The unique property of porous concrete pipes is that infiltration of water takes place over the entire surface, so that in effect the pipe-line enjoys the best characteristics of a rubble drain with the additional advantage of a central duct for the rapid removal of water.

These pipes have a wide application, and are used under road verges, for subsoil drainage, and for the removal of surface water.

Asbestos-Cement Pipes

The asbestos fibres in asbestos-cement may be compared somewhat with steel reinforcements in reinforced concrete. The tensile strength and flexibility of the fibres and the crushing strength and hardness of Portland cement combine to produce in asbestos-cement a material of great toughness.

The process of manufacture of asbestos-cement pipes is entirely different from that used in making concrete pipes. The structure of the pipe is built up from a continuous film of asbestos-cement, and the resulting product is a very strong and durable pipe.

These pipes were first produced in Italy, and are widely used in place of metallic pipes, especially for the conveyance of water.

Furthermore, the properties of asbestos-cement pipes include a high degree of insulation from heat, cold, and electric current, immunity from decay, and freedom from incrustation. They are also fire-resistant, non-corrosive,

and impervious to weather and sea-water. They resist normal external and internal pressures, and harden, thereby gaining strength with age.

FIG. 137

Data for Asbestos-Cement Pipes

Class.	Working pressure		Nominal bore in inches.
	Head of water (ft.).	lb. per sq. in.	
A . .	100	43·3	4, 6, 8, 9, 12, 15, 18.
B . .	200	86·7	3, 4, 5, 6, 7, 8, 9, 10, 12.
C . .	300	130	1½, 2, 3, 4, 5, 6, 7, 8.
D . .	400	173·4	1½, 2, 3, 4, 5, 6. 7.

Asbestos-cement pipes can be cut easily and quickly with a hack-saw, drilled, and screw-threaded.

These pipes are made to British Standard Specification No. 486 of 1933, and are obtainable in four different classes: A, B, C, and D, as listed in Fig. 137.

They are made in lengths of 4 metres (13 ft. 1½ in.) for 4-in. bore and upwards, except 4 in. in Class A, which is made 3 metres long (9 ft. 10⅛ in.), as are all sizes in other classes smaller than 4 in. in diameter, excepting 1½-in. Class C pipes, which are made in 2-metre lengths (6 ft. 6¾ in.).

Rubber rings may be used in jointing for these pipes, thus providing a fair degree of flexibility for a pipe-line.

The Stanton Ironworks Co., Ltd., manufacture concrete-lined iron pipes by a special patented process, the concrete being introduced into the bore of the rotating pipe by means of compressed air. This is known as a centrifugal spun process, and during the depositing and spinning of the concrete it is also vibrated until the maximum density is obtained (see Fig. 138).

The joints may be formed by using a gasket and "compo" (cement mortar), as described earlier and shown in Fig. 131, or by using any of the well-known proprietary compounds

sold for the purpose. Amongst those used extensively for this type of pipe-joint is the "Philplug" cold caulking compound, made by Philplug Products, Ltd., which consists of a special mixture of cement and asbestos. It can be obtained either in fibre form (P.C.3) or in cord form (P.C.4).

All that is necessary to form a joint when using the Phil-

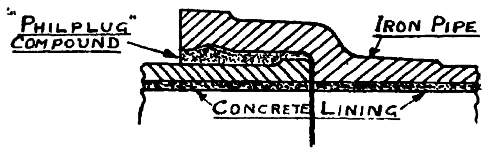

FIG. 138.—CONCRETE-LINED IRON PIPE JOINT
Reproduced by courtesy of Philplug Products, Ltd.)

plug, is to moisten the material and ram it well into the joint by using a caulking tool, and allow to set and harden.

A joint constructed with this material will stand a working pressure of up to 60 lb. per square inch immediately it has been made, 100 lb. per square inch twelve hours after, 200 lb. at twenty-four hours after, and 300 lb. per square inch forty-eight hours after.

CHAPTER X

COLOURED CONCRETE AND ITS USES

CONCRETE may be coloured by the introduction to the mix of various coloured pigments. A white concrete may be produced by using "Snowcem"—a white waterproof cement paint. This latter material is suitable also for use on concrete, sand-lime brickwork, stonework, asbestos sheets, fibre boards, etc., but should *not* be used on surfaces containing gypsum plaster.

Snowcem is available in 7-, 14-, 28-, 56-, and 112-lb. airtight tins. It should be mixed, for use with water, according to the directions supplied with each tin. Before use it should be stirred to the consistency of paint; it is then ready for use.

Snowcem should be applied within one hour of mixing, and during use it should also be stirred frequently. It is applied in a somewhat similar manner to distemper, and may be employed either for internal or external wall surfaces, on which it provides an impervious finish.

This material can be applied either with a whitewash brush or by spraying.

Although originally this product was supplied in white colour, it is now obtainable also in the following shades: cream, deep cream, buff, pink, silver-grey, and duck-egg green.

1 cwt. of Snowcem for *two-coat* brushwork will cover from 100 to 200 sq. yd., according to the suction of the surface to which it is applied.

It is advisable, before applying Snowcem to any surface of an absorbent nature, first to saturate the surface with clean water.

Cemprover

This is a liquid for use in conjunction with Snowcem cement paint, cement finishes, or concrete. It has been specially produced so as to widen the field of application of Snowcem, in such a manner as to convert normally "unsuitable" surfaces into those suitable for its adoption and use.

In this respect brickwork containing sulphates and surfaces finished with gypsum plaster may be suitably treated, thereby providing additional weather protection.

Cemprover is supplied in four grades, each of which possesses specific qualities, as enumerated herewith :—

Grade 1 (*for use with Snowcem*) :

(*a*) For application to dry bricks containing sulphates.

(*b*) For application to dry surfaces containing gypsum plaster.

(*c*) For application to surfaces which may have been treated previously with distemper, limewash, or most types of camouflage paint.

(*d*) For application to smooth and for non-absorbent surfaces, such as concrete moulded against metal formwork (or shuttering).

Grade 2 :

For use with "Cullamix" (Colorcrete and special sand)—to be described later—for application as a "stipple" finish.

Grade 3 :

For use as a surface dressing for concrete floors in order to prevent "dusting".

Note.—This grade is supplied in two forms :

(*a*) Matt (dressing for industrial concrete floors).

(*b*) Polished (dressing for domestic and coloured concrete floors).

Grade 4:

To provide a "key" for rendering on smooth concrete surfaces.

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Cullamix

This is used for the decorative treatment of walls. It is a composition supplied in a variety of pastel shades, and

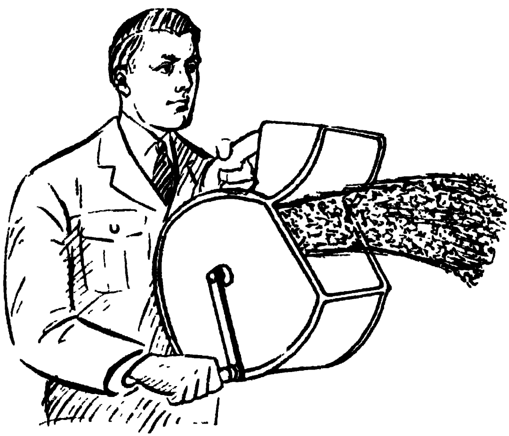

FIG. 139. SPATTER-DASH MACHINE

may be applied direct to concrete, either as a "spatter-dash" or a smooth float finish.

It is, however, NOT recommended for direct application to brickwork, but may be applied after suitable "undercoat" treatment.

Cullamix provides an excellent "Tyrolean" open-textured finish when applied by a small, hand-type operated machine (see Fig. 139) and does not readily absorb rain water.

It may be used also in two-coat, or three-coat form to

provide combined weather-proof and decorative finishes to concrete or brickwork, the object of the undercoats being to form suitable keys.

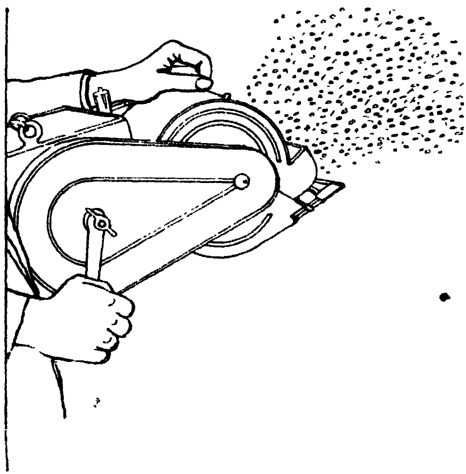

FIG. 139a.—ANOTHER TYPE OF SPATTER-DASH MACHINE

Snowcrete

Snowcrete is a grade of Portland cement, usually of white colour but it can now be supplied also in two shades of cream.

It is used in a similar manner to Portland cement.

Colorcrete

As its name infers, this material is used for making coloured concrete and is a rapid-hardening Portland cement, which may be supplied in a variety of colours of pigment basis.

It is used in the same way as normal rapid-hardening cement.

Water-Repelling Cements

In cases where absolute water-tight concrete is essential, both ordinary Portland cement and "Ferrocrete" rapid hardening cement can be supplied with a water-repellant compound added to them. Moreover, water-repellant Colorcrete and Snowcrete can be obtained, and are recommended for tanks and other water-containing structures, but all colouring matter and special compounds of a pigment nature added to cement tend to decrease slightly the strength of the resulting concrete, so for most small jobs a well-mixed dense concrete will usually suffice. It is also advantageous, where water-tightness is desired, to increase slightly the percentage of cement to the mix, and during the pouring of the concrete to ram it thoroughly.

As an extra precaution, the surfaces of the concrete may be rendered—i.e., by applying a coating of asphalt or Bitumastic solution.

Rapid-Hardening Cement and its Uses

From the brief mention of rapid-hardening cement given earlier, the reader will have learned some of its advantages, such as the earlier stripping f shuttering and early use of roads, etc.

Its use can often play a very important part when employed for urgent contracts which must be completed on time under penalty, etc., and also assists in concreting when frost threatens.

"Tinting" or Colouring of Concrete

In order to match various natural stones, in concrete building construction work, in certain cases it is necessary to add a colouring pigment to the cement, in addition to selecting a special grade of aggregate.

It is essential to grind the pigment with the cement before mixing the concrete. It is preferable therefore, to arrange with the cement suppliers for deliveries of cement ground with the pigment to the purchaser's requirements.

Owing to the extreme fineness of cement, merely adding the pigment and mixing the two ingredients is not sufficient.

The proportion of pigment is best found by experiment, until the desired shade is obtained. The intensity of

FIG. 140

Table of Colour Pigments

Required colour of concrete.	Pigment.
Yellow.	Barium chromate, or yellow ochre.
Grey to black.	Manganese black.
Brown.	Burnt umber.
Pink to red.	Red oxide of iron, or crimson lake with an alumina base.
Blue.	Prussian blue.

Note.—Iron oxides are not very reliable.

colour softens as the concrete hardens, so a final permanent colour is not attained until after a few days.

Fig. 140 gives a table of various pigments used to produce different coloured concretes.

In addition to the use of pigments for colouring buildings, attractive coloured paving-slabs can also be produced, which, being of the same composition throughout, show no variation in colour after heavy wear.

CHAPTER XI

LIGHT-WEIGHT CONCRETE

ALTHOUGH, as stated earlier, ordinary concrete weighs approximately from 112 lb. per cubic foot up to 150 lb. per cubic foot, " light-weight " concrete, or mortar, can be produced which has a density as low as 50 to 60 lb. per cubic foot, and in the case of foamed slag, as low as 30 lb. per cubic foot.

Aerated cement mixtures can be produced having a density of between 35 and 50 lb. per cubic foot.

The chief advantage of light-weight concrete is its heat-insulating property, which increases as its weight decreases. Therefore, if the weight of the concrete is halved, its insulating property is almost doubled, but its strength is greatly reduced.

Light-weight concrete may be made by using light-weight aggregates, such as clinker, foamed slag, or pumice, or by omitting the fine aggregate, as in what is termed " no-fines " concrete.

Furthermore, another type of light-weight concrete can be produced by aeration, or the formation of small gas bubbles (or air cells), which also provide a certain amount of flexibility; but this is a very specialized technique and is outside the scope of this book.

Sawdust has also been used with success for producing light-weight concrete, and more recently a modern product known as exfoliated Vermiculite has been used, since it has been found to possess excellent insulating qualities.

" Clinker ", which is the residue from burnt coal or coke, and contains very little combustible material, has been used extensively—especially for producing clinker-blocks—

or breeze-blocks for internal partition walls of buildings. Such aggregate should comply with British Standard Specification No. 1165: "Clinker Aggregate for Plain Concrete".

"Foamed slag" is produced from blast-furnace slag by treating it, whilst in the molten state, with a controlled quantity of water, which causes the slag to swell into a porous cellular mass. This material when used for light-weight concrete should comply with British Standard Specification No. 877.

"No-fines" concrete may be made with either light-weight aggregate or heavy aggregate, such as gravel or granite, etc. The usual grading for the aggregate is $\frac{3}{4}$–$\frac{3}{8}$-in. with 5 to 10 per cent. passing a $\frac{3}{8}$-in. sieve. The usual mix is 1 to 8 by volume for heavy aggregate, and 1 to 6 by volume for light-weight aggregate. Water in quantity sufficient only to ensure that the cement paste completely coats the aggregate should be used. To prevent the balling of the cement, only half the cement should be added to the mixer at first, the remainder being added after the aggregate and cement have been partly mixed. This is particularly important where an ordinary drum-type concrete mixer is used.

However, special trough-type and paddle-type mixers for which it is claimed no "balling" occurs, are available for light-weight concretes, and provision is made for discharging efficiently the stiff or semi-dry mixes from the machines.

Fig. 120 shows an internal view of the "Winget" trough mixer, in which the blades are positioned alternately left hand and right hand, to provide positive mechanical treatment.

Fig. 141 depicts the "Winget" whirlpool mixer, and Fig. 142 shows a diagrammatic view of its impellers inside the mixing-pan. This machine can be supplied with a pre-foaming attachment for making air-entrained products.

Fig. 143 gives a table of the properties of light-weight concretes as compared with those of a normal dense concrete.

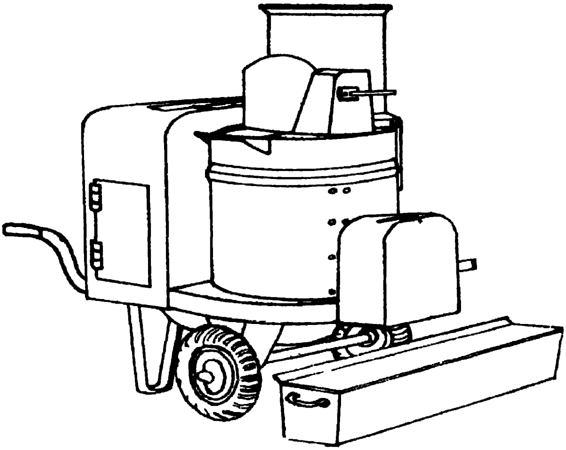

FIG. 141.—WINGET "WHIRLPOOL" MIXER

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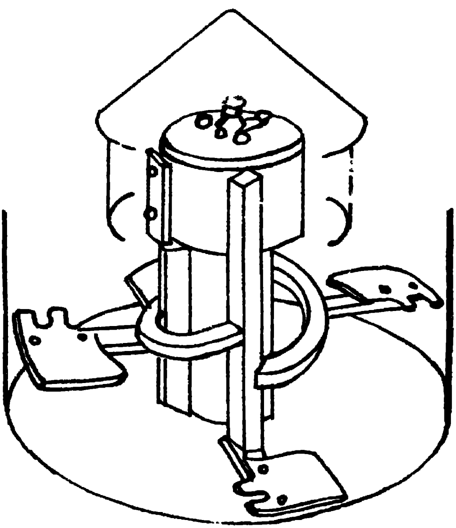

FIG. 14.—IMPELLERS

FIG. 143

Properties of Light-weight Concretes

Types of light-weight concrete.	Mix cement (aggregate by volume).	Crushing strength (lbs. per sq. inch).	Transverse strength (lbs. per sq. inch).	shrinkage Drying (per cent.).	Weight lbs. (per cubic foot).	Thermal Resistivity in dry condition.*
Dense concrete	1 : 2 : 4	4000 (Av.)	500 (Av.)	0·03–0·05	145–150	0·15
Pumice	1 : 6	200–550	100–150	0·04–0·08	45–70	0·7
Clinker	1 : 6	150–450	75–250	0·03–0·20	50–105	0·35
Foamed slag	1 : 6	800–2000	200–300	0·04–0·05	80–95	0·45
No-fines concrete, gravel aggregate	1 : 10	600–850	—	0·04	100	0·19
Aerated cement	—	200–500	100–240	0·05–0·18	35–60	0·5–1·0

* Expressed as number of hours required for transmission of 1 B.Th.U. per sq. foot for 1° F. difference in temperature between the surfaces.

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LECA Light-weight Expanded Aggregate

Leca aggregate is made from certain clays which are heat-treated up to a temperature of 1,100° C. The heating causes the clay to swell to several times its original volume, thereby forming a spongy structure which is caused by the liberation of gases during the heating process. The resultant product consists of hard, vitreous aggregate of cellular structure.

The heating (or firing) of the clay is performed in rotary kilns, very similar to those used for Portland cement manufacture, and the manufacturing process employed for making "Leca" at many stages bears a close resemblance to that of cement manufacture.

Unlike many light-weight aggregates, Leca is entirely free from active chemicals, organic compounds, or combustible materials. Moreover, Leca aggregate has no action on steel, so it can be used for purposes for which other types of light-weight are prohibited on account of their corrosive action on steel reinforcement.

Leca produces concrete which is light in weight but relatively high in strength. It therefore combines excellent qualities as a thermal insulator with a high resistance to fire, frost, dampness, and shock.

The material is supplied in three grades, as follows :—

Coarse (passing $\frac{3}{4}$-in. sieve, but retained on a $\frac{3}{8}$-in. sieve) having a weight (when dry) of 20–25 lb. per cubic foot.

Medium (passing $\frac{3}{8}$-in. sieve, but retained on a No. 7 sieve) having a weight of 25–30 lb. per cubic foot.

Fine (passing a No. 7 sieve, i.e., approximately $\frac{1}{10}$ in.) weighing 38–42 lb. per cubic foot.

Light-weight

The weight of concrete made with Leca depends on the mix and degree of consolidation as required for different purposes, but it ranges from 40 lb. upwards per cubic foot.

Ordinary concrete weighs about 140 lb. per cubic foot. The weight of a Leca brick is less than half that of an ordinary clay brick.

Floor Screeds

Coarse Leca should be used for floor and roof screeds, and laid to a minimum thickness of 2 in.

A suitable mix is 6 parts of Leca to 1 part of Portland cement, surfaced after a minimum period of twenty-four hours, or when the screed is dry, with ½ in. thickness of mortar, composed of 3 parts sand to 1 part of Portland cement.

Roof Screeds

The mix here is 8 parts coarse grade Leca to 1 part of Portland cement, surfaced after a minimum period of twenty-four hours, or, when the screed is dry, with a mortar of 3 parts sand to 1 part of Portland cement.

If the roof is to be finished in asphalt, the thickness of the mortar should be ¾ in.

In order to obtain the maximum thermal insulation from a Leca concrete roof-screed, and to prevent possible damage to interior decoration due to the penetration of moisture, it is essential that trapped water shall not lie in the interstices of the Leca concrete at the time the cement and sand topping are being laid.

Leca concrete can be cut cleanly by a saw. It can also be "chased", and nails can be driven into it.

The proportions of the various grades and the proportions of aggregate to cement will have to be selected according to the type of concrete required.

When light-weight and thermal insulation are the main properties desired, the aggregate should be all Leca. When strength is of primary importance, a proportion of sand should be added to the mix; this will, however, increase the weight and reduce the thermal insulation proportionally.

Mixing of Leca

When mixing Leca concrete, the Leca aggregate should first be fed into the mixer, and whilst it is turning over, some water should be added. There should be no free water in the mixer at this stage, other than that on the surface of the Leca. The cement should then be added and more water, as required. Mixing should proceed for about five minutes. The cement and water grout must be fluid, but with some viscosity. It should never be mixed to a semi-dry consistency. After the completion of mixing the concrete should look shiny (or glossy) with wet grout. When using sand with the mix, the sand should be added immediately after the cement.

The most suitable types of mixer for Leca concrete are the "cum-flow" or counter-action mixer, or the Archimedian screw type.

Uses

Among the many uses for Leca are the following: Precast blocks, bricks, slabs, backing for cast stone, or decorative concrete, facings, roof and floor screeds, dry filling, etc.

Since one of its chief properties is that of thermal insulation, Leca is being used extensively for this purpose.

The principal function of an insulating material is to prevent heat or cold being transmitted through the walls, roof, and floor, thereby maintaining an even temperature inside a building despite variation in outside temperature.

The thermal conductivity of a building material is expressed as its "k" value, and is the quantity of heat in terms of British Thermal Units conducted each hour through 1 sq. ft. of the material 1 in. thick when the temperature of the two surfaces differs by 1° F.

The "k" value of medium grade Leca is 0·9 and the "k" value of Leca concrete, with moisture content at less than 0·25 per cent. is between 1·1 and 1·8 for a density variation of between 50 and 80 lb. per cubic foot.

The reader will realise that the "leaner" the concrete mix in which Leca is used, and the lower the density of the concrete, the better is its thermal insulation value.

This is an important factor to be borne in mind when determining the mix for the specific purpose for which the concrete is to be used.

Leca without binding medium offers wide scope as an insulator when used as an infilling between cavity walls, or on top of asphalted flat roofs.

Fire Resistance

Since Leca is stable up to its manufacturing temperature of 1,100° C., it is, in itself, an excellent aggregate to use for refractory concrete with Lightning Brand High Alumina Cement. Its low thermal conductivity gives it the added advantage that heat is transmitted very slowly, thereby affording protection to structural members.

Drying Shrinkage

The usual figures obtained for Leca concrete for shrinkage are between 0·05 and 0·06 per cent.; the drying shrinkage of the Leca itself is nil.

Incidentally, British Standard Specification No. 492 and 728 for pre-cast concrete partition blocks under the drying shrinkage test call for a limit of 0·08 per cent.

Finally, concrete made with Leca aggregate is not of a brittle nature and does not readily fracture—a great advantage in handling and transport.

CHAPTER XII

PRE-STRESSED CONCRETE (INTRODUCTION TO)

In recent years much mention has been heard of pre-stressed concrete. Although this is not really a new material, its successful use has been developed rapidly during the last few years, chiefly because steel of a more suitable character has been produced.

As mentioned earlier, concrete is strong in compression but weak when used for tensile stresses, hence the employment of steel used in reinforced concrete.

If, therefore, we consider a beam made of plain concrete, and spanning a certain distance, it will at once be realised that the beam's own weight (quite apart from any load it may be called upon to carry) will cause the beam to " sag " or bend. This sagging at once puts the lower edge of the beam in tension, and, unless of sufficient cross-sectional area, may cause it to break, especially if the span is relatively large.

If, on the other hand, we use a beam of similar cross section, but incorporate steel bars in the lower portion, the steel will resist the tensile stress derived from the sag of the beam, and thus assist in preventing it breaking.

The reader, after due reflection, may suggest that if the beam were cambered or curved upwards (convex), this would tend to deflect, and thus straighten when loaded, especially if the ends of the beam were anchored efficiently.

During such straightening tendency the concrete beam would be under a compressive stress instead of a tensile one, as in the former case. In other words, the effect of the camber in the beam is of assistance in providing for resist-

ance to the deflection when the beam sags due to its weight, plus any external load it may be called upon to carry.

Such camber is very beneficial in fact, as will be readily appreciated, and it is more serviceable than beginning with a straight beam, which under loading develops a sag of concave form. This camber is an advantage, and in practice often forms the basic principle of reinforced-concrete bridge construction.

The principle will perhaps be more easily followed if the reader considers for a moment an " expansion bend ", as used in a steam main, to provide suitable expansion for a long length of piping. If such a bend is installed in the normal space between the open lengths of steam pipe (when cold), directly hot steam is passed through the installation, the expansion bend contracts between the flanges due to the pushing effect derived from the *straight lengths* of hot steam pipe on both sides of the bend. In order to counteract or neutralise this effect, instead of a gap being left between the straight lengths of pipe equal to the space between the flanges of the bend, the gap is made slightly larger and the bend is strained slightly to couple up, so that when in use and carrying hot steam, instead of the strain being all in one direction, it is somewhat counterbalanced (see Fig. 144).

Now, returning to the consideration of pre-stressed concrete, most readers will, at some time or other, have noticed a small child playing with a box of wood bricks. They may have also noticed the child's surprise when he discovers that by packing a number of similar bricks together edgeways on the floor he can remove the whole number bodily by placing the palms of his hands over the end bricks and pressing them ; or the reader may have noticed a librarian removing a number of books from a shelf by similar means (see Fig. 145).

Here we have an elementary example of the principles of pre-stressed concrete.

It will be appreciated that if some means can be devised of creating such compressive stresses on the ends of a

horizontal concrete beam, and sufficiently large to counteract the load of the beam (plus any external loading), the beam will remain intact.

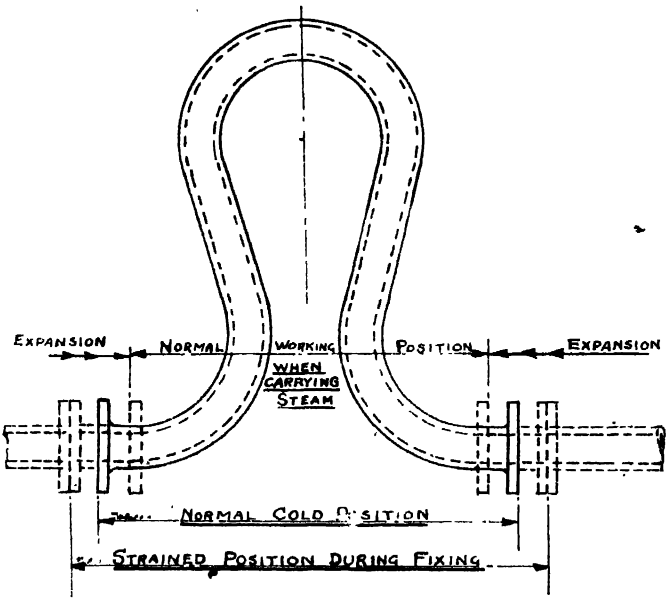

FIG. 144.—ANALOGY OF STEAM PIPE BEND

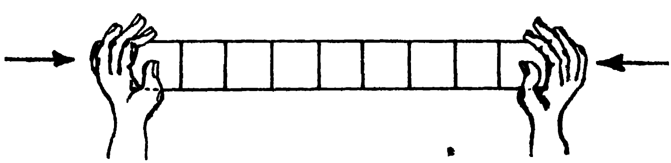

FIG. 145.—MOVING CHILD'S TOY BRICKS BETWEEN HANDS

In practice these principles are now used successfully by embodying steel wires integrally with a concrete beam

and highly stressing the wires by tensile forces during the pouring of the concrete, so that later, when the tension on the wires is released, the reaction created retains the fibres of the concrete under permanent compressive stress.

This principle may be readily followed if the reader considers *strands* of *elastic* being used instead of steel, whereby the reaction of the elastic will bond together the concrete once the ends of the stretched elastic are released.

The analogy of elastic is used because the quality of steel employed for pre-stressed concrete plays a very important part in its eventual success, as will be seen later, since it has now been proved that the early attempts made at pre-stressing concrete and subsequent failures were entirely due to the steel employed being unsuitable.

So far it will have been realised that the technique of pre-stressing is a type of construction whereby initial compressive stresses are set up in a member to resist or counterbalance the tensile stresses produced by the load.

In pre-stressed concrete the steel is not used as reinforcement, but as a means of producing a suitable compressive stress in the concrete. Therefore any beam (or member) made of pre-stressed concrete is permanently under compression, and is consequently devoid of cracks—under normal loading, or so long as the "elastic limit" is not exceeded.

Moreover, it should also be noted that pre-stressed concrete must be used in conjunction with a normal "factor of safety", similarly to other structural work.

Early attempts at pre-stressing concrete were first made by Freyssinet, who used rods of *ordinary "mild" steel* for his construction tests.

Now the elongation of this steel when stressed to its normal working value of 16,000 lb. per square inch is about ½ in. per 66 ft. length.

It was later found that in a few weeks this stretching of the steel disappeared from the concrete, and it was dis-

covered that this was due to shrinkage and "creep" of the concrete under load. The creep therefore counterbalanced the effects of the original stretch produced in the mild-steel rods, thereby destroying the benefits of pre-stressing.

Since the introduction of "high-tensile" steel wires of cold-drawn type, which will stretch as much as $3\frac{1}{4}$ in. per 66 ft. length when stressed to 16,000 lb. per square inch, these have proved very successful, for although a certain amount of shrinkage and creep may continue to take place in the concrete, there still remains ample stress in this steel to retain the pre-stress in the concrete.

In practice, for the construction of pre-stressed concrete, beams, wires, or cables composed of "high-tensile" cold-drawn steel are laid in the mould longitudinally. The ends of the wires at one end of the mould are either secured in a special "sandwich plate" with wedges, or screw-threaded and fitted with nuts and anchored.

At suitable intervals spacers or distance pieces are provided, to retain the steel wires in their relative positions.

At the other ends of the wires a hydraulic ram (constructed on a steel frame) is installed, to which each wire in turn is attached and stretched a pre-determined amount.

This is indicated on a dial attached to the hydraulic ram.

When the stressing of the steel wires has been completed, cement grout is injected under pressure into the concrete as a protection for the wires, and to thus fill up the spaces provided for them. However, in some cases of pre-stressed concrete construction the wires are first pre-stressed and the concrete is later cast around them. When the concrete has acquired sufficient strength, the stress on the steel is released and retained by bond with the concrete.

For some types of construction the steel is induced to bond better in the concrete by indenting the wires.

The most common method of pre-tensioning is by what is known as the "long-line" system, whereby a large number of units can be produced at a time.

In this case the wires are stretched between anchorages at opposite ends of a long " stretching bed ". Spacers are positioned at suitable intervals, and the concrete is cast around them. After the concrete has set and hardened sufficiently the wires between each unit are cut.

With this type of construction the concrete is vibrated, by mechanical means, and finally each unit is effectively " cured " prior to delivery for use.

A further system known as " post tensioning " is sometimes used in which the concrete units are cast first.

The wires (or cables) may be cast in with the concrete, but are prevented from binding with it by some form of sheath (or tubular-shaped holes may be provided longitudinally in the concrete and the wires threaded through after the concrete has hardened). The wires are then anchored and stressed, after which they are " grouted-in " by grout fed under pressure, as mentioned earlier.

The steel used (both for pre-stressing and post-tensioning) is usually from 0·06 in. to 0·276 in. in diameter, and varies in tensile strength from 90 tons per square inch up to 150 tons per square inch for the larger size mentioned.

Since at normal temperatures the concrete requires several days to set and harden sufficiently for the removal of the moulds, various methods have been adopted to accelerate these processes.

Steam has been used successfully during recent years, and is now extensively used for the curing, since when steam curing is employed the concrete may attain a strength in a few hours equal to that reached with normal curing in twenty-eight days.

Figs. 146 and 147 show details of the Freyssinet systems of anchorage and jack operation.

The " Magnel–Blaton " method of anchorage consists of steel plates with two trapezoidal grooves in the upper surface and two in the lower.

A machined steel wedge fits into each slot and fixes two wires in each groove (see Fig. 148).

The "sandwich" plates, as they are called, are arranged in layers, the number depending on the size of the cable. Each sandwich plate anchors eight wires. The assembly bears upon a cast-steel distributing plate with a central hole through which the cable passes.

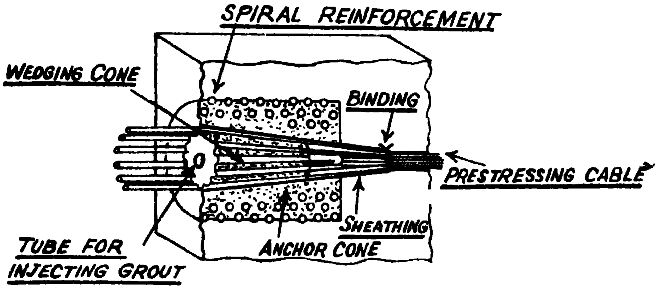

FIG. 146.—FREYSSINET TYPE ANCHORAGE

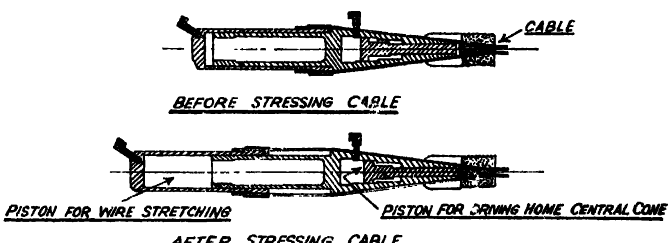

FIG. 147. FREYSSINET JACK OPERATION

The purpose of this plate is to distribute the pre-stressing force at its point of application to the beam or unit.

On leaving the anchorage the wires converge for a short distance, and thenceforward are held at fixed distances of about $\frac{3}{16}$ in. one from another by spacer grilles (see Fig. 149).

The cable may be cast into the concrete, in which case it is wrapped in thin sheet steel to prevent bond, or may

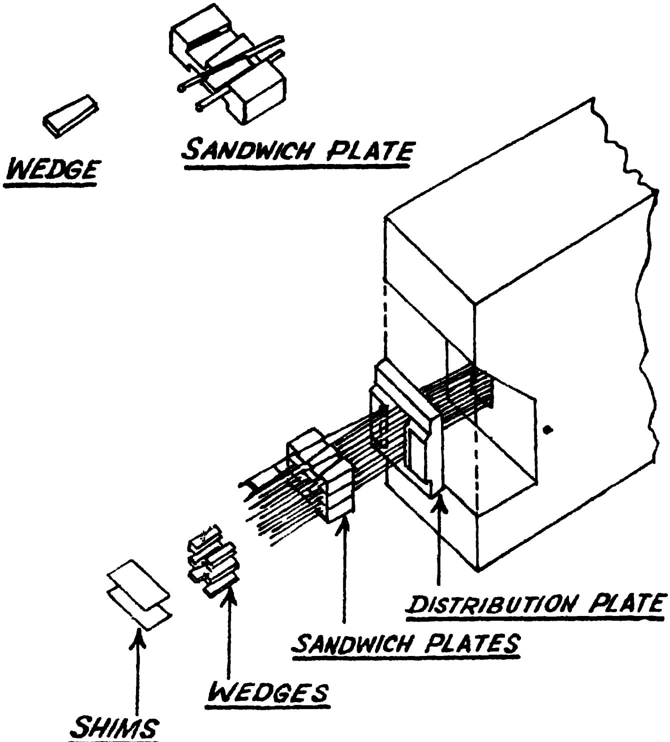

FIG. 148.—EXPLODED VIEW OF MAGNEL–BLATON ANCHORAGE SYSTEM

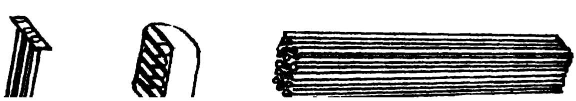

FIG. 149.—SPACER GRILLS

pass through a housing in the concrete section. It is normally grouted up or otherwise protected. Grouting is effected by a tube joining the cable at an angle and reaching

the open at a point adjacent to the anchorage. The grouting is performed under pressure.

A hydraulically operated stressing jack is then applied, the wires being gripped two at a time and stressed by the interaction of the piston at the one end and the bearing on the anchorage at the other end. The wedge for the two wires is then driven home and the tensioning of the next two wires proceeded with. When completely stressed, the anchorage is normally covered with concrete for protection.

Both the Freyssinet and Magnel–Blaton systems may be used for solid or hollow beam construction, and both methods employ straight or curved cables.

A further system of post-tensioning is the "Lee–McCall" method, which has been developed rapidly both in this country and abroad.

In this system alloy steel rods are used instead of wires or cables, to produce the pre-stress. Although the concrete casting process is similar to that already described for post-tensioning, the steel rods in this case may be from ½ in. to 1⅛ in. in diameter. The rods are anchored at each end by a special nut which screws on to each rod end and bears against the concrete through special packing washers and steel distribution plates. A special form of screw-thread is used which enables the load to be transferred by degrees from the rod to the nut, so that stress concentrations are, as far as possible, eliminated (see Fig. 150).

The nut has a tapered thread and is designed to lap approximately ⅛ in. over the end of the thread on the pre-stressing rod, as shown also in Fig. 150, at "X".

An outstanding feature of this system is that the pre-stressing can be applied in stages, and repeated un-stressing and re-stressing operations are possible at any time prior to grouting in the rods. The whole of the loss of pre-stress which occurs in the early life of the unit through shrinkage and creep in the concrete may be restored if necessary by re-application of the stressing procedure.

The stressing force is applied to the rods by a simple

hydraulic jack of 45 tons capacity reacting against the distribution plate, and to which can be attached adaptors to fit any size of bar to be stressed.

Fig. 151 shows the arrangement both before and after stressing, and Fig. 152 shows the stressing jack arrangement.

Pre-stressed concrete, in addition to being used for beams, is now employed extensively for columns, pipes, and cylindrical water-towers, storage tanks, etc.

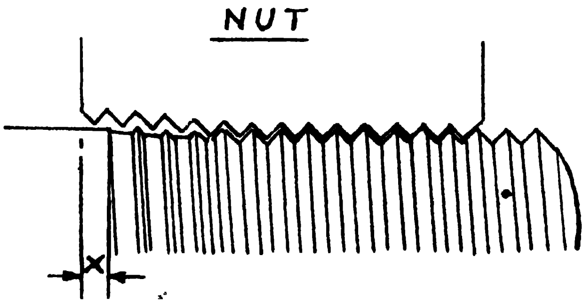

FIG. 150.—SPECIAL SCREW THREAD

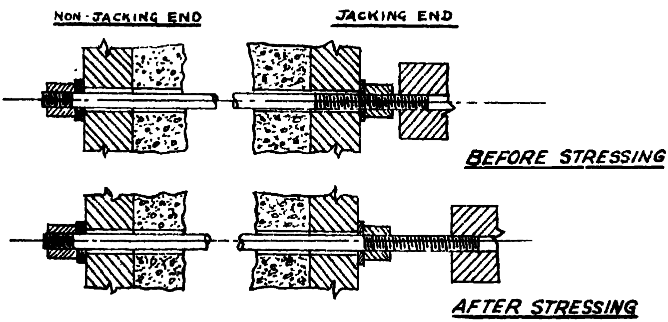

FIG. 151.—LEE-MCCALL PRESTRESSING UNITS BEFORE AND AFTER STRESSING

Furthermore, when using pre-stressed concrete, as compared with normal reinforced concrete, the quantity of steel used in the former is very much less, thereby effecting

a great saving. Although a certain amount of work is involved in the pre-stressing (or post-tensioning) processes, there is a great saving of labour in the handling and bending of reinforcements.

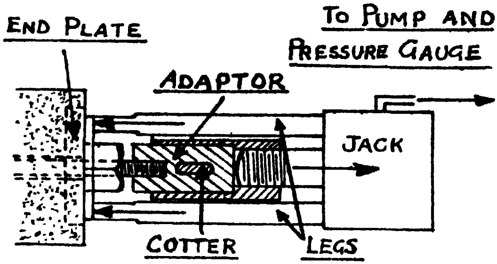

FIG. 152.—ARRANGEMENT OF STRESSING JACK

Pre-stressed Concrete Cylindrical Tank Construction

Pre-stressing has been applied to tank-wall construction by forming steel bands around the perimeter in a similar manner to that used for wooden barrels, whereby the steel hoops resist the internal pressure exerted by the contents.

Moreover, tank floors and dome-shaped roofs have been constructed successfully by using pre-stressed concrete.

Detailed methods employed differ slightly, but all involve the general principles adopted for pre-stressed concrete.

Three types of joint can be used between the floor slab and the walls :

(*a*) the fixed joint (monolithic) ;
(*b*) the hinged joint ;
(*c*) the sliding joint.

For tank constructions which are to contain liquids, and therefore must be impermeable, a good quality of dense concrete must be used. A suitable mix is 1 : 1½ : 3, and using well-graded aggregate.

Floor Construction

When the floor-slab is cast, provision is also made for the pre-stressing cables by forming ducts in which to place them. The ducts may be made by using inflated rubber tubes which are later withdrawn, or by leaving channels.

It is usual to incorporate two layers of cables each at right angles to the other, but in some systems three layers are used—two parallel (near the top and bottom of the slab), and the other at right angles to the former and in the slab centre (see Fig. 153). The cables are anchored at one

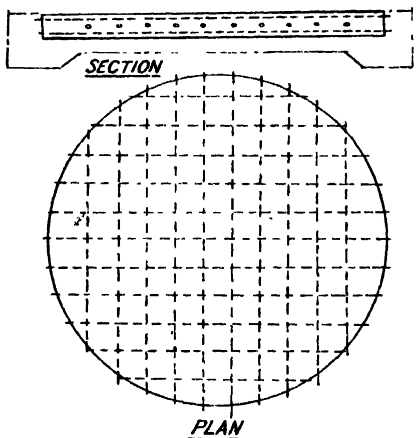

FIG. 153.—PRESTRESSING CABLES IN TANK FLOOR SLAB

end and stressed from the other end by using hydraulic jacks. After stressing (and after the rubber tubes have been withdrawn), the ducts are filled with grout under pressure.

Wall Construction

This is cast in shuttering by using normal methods, and is usually vibrated. In most cases a light steel skeleton framework is also incorporated and steel wire mesh is used as light reinforcement.

At suitable intervals vertical pockets or holes are provided for the pre-stressing cables (or rubber tubes may be used for this purpose). The cables are usually anchored at the base and stressed from the top end (see Fig. 154).

In some designs, however, instead of providing holes vertically in the centre of the concrete walls, grooves are left in the inner and outer faces of the walls in which to place the pre-stressing cables (or wires) (see Fig. 154*a*).

The concrete walls may be cast in complete circle formation and in suitable "lifts", or can be cast in quadrants; the joints later being filled with grout.

Horizontal pre-stressing cables (or wires) are then placed around the outer perimeter of the tank, and at suitable spacing, anchored and tensioned.

FIG. 154 FIG. 154*a*

ALTERNATIVE SLOT TYPES FOR VERTICAL PRESTRESSING CABLES IN TANK WALLS

The Magnel–Blaton tensioning system is frequently used, whereby two wires from each direction around the tank can be stressed at one operation.

The anchor "joints" should also be "staggered", so that all do not occur at one position.

After pre-stressing has been completed, a protective coating of 1 in. thickness of pneumatically applied cement/sand mortar is sprayed over the external surfaces.

Roofs

In cases where a tank has to be provided with a roof, it is usually of dome-type construction.

One form is by using arch-shaped ribs of R.S.J. construction, the ribs extending radially from a central steel ring to the perimeter.

Pre-cast concrete units of either "I" beam or channel section are then laid on the steel ribs transversely, and covered with a screed coat of concrete which also bonds together the pre-cast units. As a further weather precaution the screed concrete coat can be given a final coating of asphalt or bituminous solution (Fig. 155).

Note.—The foregoing is not a pre-stressed roof, but of orthodox concrete construction.

If a pre-stressed concrete roof is desired of the dome type, arch-shaped ribs must be employed on which to carry the formwork, and concentric rings are also incorporated.

A layer of concrete is then cast and light-wire mesh is

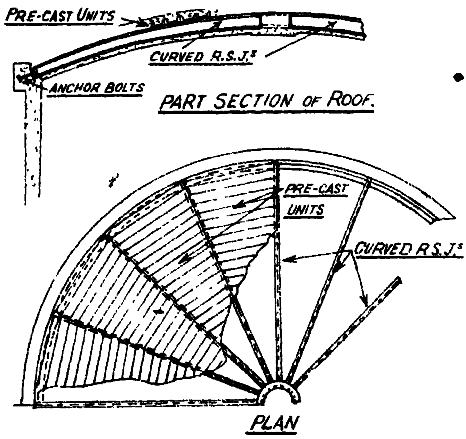

FIG. 155.—TYPICAL DOME ROOF CONSTRUCTION

used as reinforcement. Later one or more layers of prestressing wires are wound around the dome ring and stressed. Finally the wires are covered by pneumatic concrete.

Pre-Load-Type Construction

Another well-known form of pre-stressed tank construction is the "PRE-LOAD", and by such methods tanks up to 320 ft. in diameter have been successfully constructed.

A special feature of pre-load construction is that after the walls have been cast by normal methods, or by using pneumatic mortar, a continuous layer of pre-stressing wire is wound around the outer perimeter in a slow helix form. The wire is laid and pre-stressed by a machine which travels around the tank wall and is suspended from a carriage on the top of the wall.

After all the pre-stressing wires have been laid and stressed, a coating of pneumatic mortar is applied.

During the laying of the horizontal wall wires safety clamps are fixed in two pairs on three adjacent wraps of

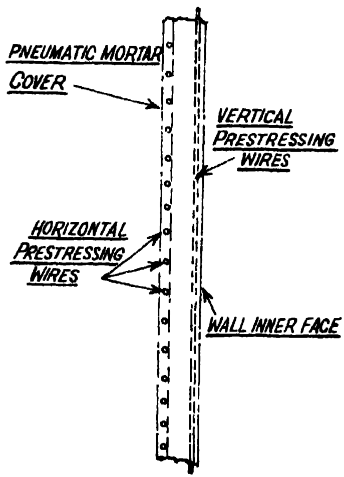

FIG 156.—SECTION OF "PRELOAD" TYPE TANK WALL

wire. Should a wire break later these clamps prevent the loss of all the wraps previously laid.

When one coil of wire has been used up, a further coil can be spliced on.

The height of the machine can be adjusted to suit the work, and it can lay wires at the rate of 7 miles per hour.

Vertical pre-stressing wires are incorporated in the walls in a manner somewhat similar to that previously described, but in the inner face only (Fig. 156).

Floors and dome roofs may be formed for this type of construction similar to those described earlier.

Tank Linings

These depend on the nature of the liquid the tank will contain.

In certain cases no lining whatever will be required, but some chemical liquids may require special linings, either of a rubber-bitumen composition or asphalt, etc. Recently certain plastics have been used for tank linings and have been applied by a spray.

Manholes or pipe connection holes may be formed in the tanks in the normal way, and the pre-stressing cables arranged to clear them.

Note.—Close supervision must be given to the workmanship at all stages of construction for pre-stressed concrete work.

CHAPTER XIII

VACUUM CONCRETE (INTRODUCTION TO)

A TYPE of concrete recently produced in France, and which is rapidly being developed both on the Continent and in America, is known as " Vacuum " concrete.

It is really, in effect, a special application or treatment of ordinary concrete, whereby the surplus moisture and air are rapidly extracted by suction, to assist in the hardening of the concrete.

After suitable treatment (in some cases of only fifteen minutes or so), ordinary concrete may have the shutters removed and the concrete is then sufficiently hard for persons to walk on it without showing any impression or having any ill effects.

Columns thus treated may have the shutters removed within a few minutes of the concrete being cast or poured.

Briefly, the process consists of using a fine cloth filter on the inner faces of the shuttering. At certain positions holes are made through the shutters, to which tubes are attached and connected to a suction fan (or " exhauster " pump).

During the pouring of the concrete it is also vibrated by either electric or mechanical means. When a certain quantity of concrete has been poured, vibrated, and thus partly consolidated, the exhauster pump is set in motion. This sucks out any surplus water and air, so that the concrete is permitted to consolidate and harden in a few hours, equal to, or even exceeding, the degree of hardness reached in several days by normal methods.

The use of the fine filter cloth prevents any small particles of cement and sand being withdrawn, so their benefit is retained.

Originally the system was employed for beams, floors, and columns, but it has now been extended to the use of concrete pipes, culverts, tanks, and other structures.

The number and spacing of the pumps or exhausters depend on the size of the job, but several units may be employed collectively, at suitable distances apart throughout the job.

For culvert construction a plant has been devised to operate on rails which can thus proceed along together with the shutters as the concreting progresses, thereby constructing or laying a continuous pipe-line which sets and hardens almost immediately.

The reader will at once realize how rapidly construction can proceed by these means. In addition, there is considerable saving by the avoidance of having a large quantity of shuttering in use for several days before it can be released for work elsewhere.

The process is equally suitable for the treatment of either plain or reinforced-concrete work.

CHAPTER XIV

ESTIMATING QUANTITIES FOR CONCRETE WORK

In order to ascertain the quantities of cement and aggregate required, the total cubic capacity of the work must be calculated. The number of cubic feet (or cubic yards) of "finished" concrete must therefore be worked out.

It is erroneous to suppose a mixture of 1 part of cement, 2 parts of sand, and 4 parts of aggregate will produce "finished" concrete equal to the 7 parts in volume.

On reflection it will be realized that the cement and sand go to fill up the "voids" (spaces) between the coarse aggregate.

In actual practice the volume of the finished concrete is only slightly greater than that of the coarse aggregate used.

Moreover, for small jobs (housing estate paths, etc.) it will often suffice to base one's calculations on this principle, i.e., for every cubic foot of concrete required, to assume 1 cu. ft. of aggregate, leaving out of account the quantities of cement and sand.

Incidentally, aggregates vary in size and shape; therefore the voids also vary. Some indication can be obtained by filling a bucket with one type of aggregate and a second bucket with another type. Next pour sufficient water into both buckets until they are brimful, then (by using a sieve placed over a third, similar-sized, but empty bucket) pour the contents of bucket No. 1 on to the sieve, thus permitting the water to flow into the empty bucket.

Perform the same operation again by using the sieve over a fourth (empty) bucket and pouring on to it the contents of bucket No. 2. The variation of the water in buckets

No. 3 and 4 will give the approximate quantity of materials (cement and sand paste) required to fill the voids in both types of coarse aggregates used.

Where more exact quantities are required, these may be calculated from the table given in Fig. 157.

FIG. 157

Materials Required Per Cubic Yard of Concrete

Based on absolute volume method, with cement weighing 90 lb. per cu. ft. and 84 lb. per cu. ft. when damp and bulked 30 per cent. gravel or shingle 109 lb. per cu. ft., and broken stone 90 lb. per cu. ft.

Mix.	Type of coarse aggregate.	Cement.	Sand (damp).		Coarse aggregate.	
		lb.	cu. yd.	tons.	cu. yd.	tons.
A	Shingle	335	0·54	0·55	0·83	1·09
	Broken stone	370	0·59	0·60	0·91	0·99
B	Shingle	392	0·52	0·53	0·81	1·06
	Broken stone	432	0·58	0·59	0·89	0·96
C	Shingle	481	0·51	0·52	0·79	1·04
	Broken stone	524	0·56	0·57	0·86	0 93
D	Shingle	596	0·48	0·49	0·71	0·97
	Broken stone	653	0·52	0·53	0·80	0·87
	Shingle	813	0·43	0·44	0·67	0 88
	Broken stone	880	0·47	0·48	0·72	0·78

Example.—Find the quantities of Portland cement, sand and broken stone required for a foundation 30 ft. long by 10 ft. wide by 3 ft. thick, using Mix A.

The volume of concrete required is :

$= 33\frac{1}{3}$ cu. yds.

The amount of cement required is

370 lb. $\times\ 33\frac{1}{3} =$ 12·333 lb. = 110 cwt., or $5\frac{1}{2}$ tons.

The amount of sand required is

0·59 $\times\ 33\frac{1}{3}$ cu. yd. = $19\frac{2}{3}$ cu. yd., or 0·60 $\times\ 33\frac{1}{3} =$ 20 tons.

The amount of broken stone required is

0·91 $\times\ 33\frac{1}{3}$ cu. yd. = $30\frac{1}{3}$ cu. yd. or 0·99 $\times\ 33\frac{1}{3} =$ 33 tons.

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For work of importance it is imperative to ascertain the amount of voids in the type of aggregate to be used, and on a large construction job it is necessary also to acquire similar knowledge concerning the sand.

It is advantageous, before starting any job, to obtain all possible knowledge concerning the materials to be used and any peculiarities they may possess. Most large contracting firms have specialists who perform this work at the beginning of a job.

Those in charge of small construction jobs should also pay as much attention as possible to these points.

It is also essential to ensure at the start of a job that the materials required will be available and in constant supply throughout, and that they will not vary in quality.

In cases where "ballast" from gravel-pits or quarries is being used, it is imperative to ensure that all "over-burden" is removed before the aggregate is excavated, so close supervision to this matter must be given.

It should also be well borne in mind, when looking over and "eye-ing up" the unexcavated material in the gravel-pit with a view to ascertaining the quantity it will produce for a job, that when excavated, and therefore "loose", it does not produce the same quantity as originally anticipated. Furthermore, one should also allow for the striking of "bad patches" of material during the excavation, which, of course, must be rejected.

Many an experienced gravel-pit foreman can "eye-up" an area and estimate to within a few cubic yards or so how much that area will produce, but he cannot always be sure that a bad patch may not be struck unless he is thoroughly well acquainted with the surrounding land. The young and inexperienced engineer should therefore be wary of this.

Estimating the cost of a construction job, once the quantities required for it have been ascertained, together with ruling prices of each material, is a comparatively simple matter, provided the labour charges are also known.

Fig. 158 gives a table of materials required for a square yard of typical road surface for varying thicknesses of from 1 in. up to and including 12 in., for two types of mix as stated therein, and when using broken stone for

FIG. 158

Quantities of Materials Required Per Square Yard *of Road Surface*

(Based on loose cement weighing 90 lb. per cu. ft., damp sand (30 per cent. bulked) 84 lb. per cu. ft., *broken stone* 90 lb. per cu. ft., and shingle 109 lb. per cu. ft.).

(Using *broken stone* as coarse aggregate.)

Thickness of slab or course.	1 : 2½ : 4 mix. Cement.	Sand	Coarse Aggregate.	1 : 2 : 3 mix. Cement.	(damp).	Coarse aggregate.
in.	lb.	cu. ft.	cu. ft.	lb.	cu. ft.	cu. ct.
1	14·5	0·42	0·64	18·1	0·39	0·60
1½	21·8	0·63	0·97	27·2	0·58	0·90
2	29·1	0·84	1·29	36·3	0·78	1·20
3	43·6	1·26	1·93	54·4	1·17	1·80
4	58·2	1·68	2·58	72·6	1·56	2·40
6	87·3	2·52	3·87	108·9	2·34	3·60
7	101·8	2·94	4·51	127·0	2·73	4·20
8	116·4	3·36	5·16	145·1	3·12	4·80
9	131·0	3·78	5·80	163·2	3·51	5·40
10	145·5	4·20	6·45	181·5	3·90	6·00
12	174·7	5·04	7·74	217·7	4·68	7·20

(Reproduced by C[illegible] of The Cement & Concrete Association)

the coarse aggregate. Fig. 159 gives a somewhat similar table of quantities, but when using shingle as the coarse aggregate.

The yield of a batch of fully compacted concrete may be estimated by the fact that the volume of concrete is equal to the sum of the absolute volumes of cement and aggregates plus the volume of water. The absolute volume of loose material is the total volume of solid matter in all

FIG. 159

(Using *shingle* as coarse aggregate.)

Thickness of slab or course.	1 : 2½ : 4 mix.			1 : 2 : 3 mix.		
	Cement.	Sand (damp).	Coarse aggregate.	Cement.	Sand (damp).	Coarse aggregate.
in.	lb.	cu. ft.	cu. ft.	lb.	cu. ft.	cu. ft.
1	13·4	0·38	0·59	16·6	0·36	0·55
1½	20·0	0·57	0·89	24·8	0·54	0·83
2	26·7	0·76	1·18	33·2	0·72	1·11
3	40·1	1·15	1·78	49·7	1·08	1·66
4	53·4	1·53	2·37	66·2	1·44	2·22
6	80·2	2·29	3·55	99·4	2·16	3·33
7	93·5	2·67	4·14	115·9	2·52	3·88
8	106·8	3·06	4·73	132 5	2·88	4·44
9	120·2	3·44	5·32	149·0	3·24	4·99
10	133·6	3·82	5·92	165·6	3·60	5·54
12	160·3	4·58	7·10	198·7	4·32	6·66

Note.—Normal mixes such as 1 : 2 : 4, 1 : 1½ : 3, etc., are based on all materials being in a bone dry condition. Sand as used under ordinary conditions is always damp and bulks about 30 per cent., so that a 1 : 1½ : 3 mix should actually be specified as 1 : 2 : 3, in which allowance is made for this bulking. The above tables are based on damp sand 30 per cent. bulked

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the particles. This is computed from the weight and specific gravity of surface dry material, i.e.:

$$\text{Absolute volume} = \frac{\text{weight of material per cu. ft.}}{\text{specific gravity} \times \text{weight of water per cu. ft.}}$$

For practical purposes the specific gravity of cement may be taken as 3·1. The specific gravity of the aggregates used may, however, vary, and it is therefore best determined by test, but if this cannot conveniently be done, the following approximate figures may be taken:

Flint gravel .	2·50–2·60
Quartzite . .	2·60–2·65
Granite . .	2·70–2·80
Basalt (whinstone)	2·80–2·90
Limestone . .	2·70–2·80

Taking a mix consisting of 1 cwt. of cement, 2½ cu. ft. of sand, 4 cu. ft. of coarse aggregate and 6½ gallons of water, made with fine aggregate weighing 100 lb. per cubic foot and gravel weighing 110 lb. per cubic foot, the yield of concrete per batch will be as follows :

Cement	$\frac{112}{3\cdot1 \times 62\cdot4}$	= 0·58 cu. ft. absolute vol
Fine aggregate	$\frac{2\cdot5 \times 100}{2\cdot65 \times 62\cdot4}$	= 1·51 ,, ,, ,, ,,
Coarse aggregate	$\frac{4 \times 110}{2\cdot65 \times 62\cdot4}$	= 2·66 ,, ,, ,, ,,
Volume of water	$\frac{6\cdot5 \times 10}{62\cdot4}$	= 1·04 ,, ,, ,, ,,
Yield of concrete per batch		= 5·79 cu. ft.

Therefore the quantities per cubic yard of concrete are :

Cement	$\frac{27}{5\cdot79} \times 1$ cwt.	= 4·65 cwt.
Fine aggregate	$\frac{27}{5\cdot79} \times 2\cdot5$ cu. ft.	= 11·60 cu. ft
Coarse aggregate	$\frac{27}{5\cdot79} \times 4$ cu. ft.	= 18·60 cu. ft.
Water	$\frac{27}{5\cdot79} \times 6\cdot5$ gallons	= 30 gallons

For estimating shuttered concrete work (walls, etc.), several factors must be considered, such as the wall's height, weather, etc., since the latter plays an important part in the time available before the lower shutters can be removed and used for greater heights. The plant available for concreting high walls must also be considered. The same applies to the hoisting and fixing of the steel reinforcements, since at great heights special scaffolding will be required.

A further factor to be considered, especially in built-up areas, is congestion of the material at site and its availability just when required. Close attention must therefore be paid to having the required reinforcements at hand when

wanted as work proceeds at various heights, and not find that they have been stored beneath others not required until later. The question also arises whether to have the mixing plant at ground level and employ a hoist for elevating the wet concrete, or whether to have a concrete mixer installed at the higher level and barrow (or feed by chute) the mixed concrete.

If the latter be decided upon, substantial scaffolding will be necessary on which to erect the mixing plant, and the raw materials elevated to feed the plant. In most cases it is preferable to mix at ground level, and thus elevate only the mixed concrete.

With this system the water supply is often easier to arrange, and there is also possibly less wastage of raw materials due to spillage.

In some localities where timber is available at reasonable cost it may be preferable to use it instead of transporting steel shuttering from place to place, whilst in other areas the latter may be employed at less cost.

Moreover, since steel shutters are available in standard sizes, they can be used over and over again, whereas with timber cut for one job considerable wastage may be involved in adapting it for work elsewhere.

The quantity of water required for the concrete must be ascertained. This may not be so important for jobs in towns or cities, where a piped water supply is readily available, but for road-construction in rural areas the matter may be vastly different, and in certain cases it may necessitate using lorries with suitable water-tanks for conveying water from a stream or lake several miles away, in order to maintain an adequate supply.

The same may apply in bridge construction jobs in rural areas—even for bridges over canals or rivers whose water may be contaminated and unsuitable for concrete.

Once the construction programme has been decided upon, and the daily cement requirements have been ascertained, it is often preferable to arrange for daily consignments to

arrive at site, each in quantity exceeding only slightly the average daily consumption. This procedure thus avoids a large "build-up" or reserve of a material which, unless stored under ideal conditions, does not keep too well, especially in a damp atmosphere. A timber-floored shed is usually used as a cement store and it is helpful if, in the event of a large reserve becoming accumulated, sacks taken from the lower layers in the store are used and replaced with a fresh consignment. If such precautions are taken about every two weeks or so, there is little chance of any large cement wastage due to deterioration whilst in storage.

Summary

1. Calculate exactly how much finished concrete will be required for your job.
2. Ascertain how much cement, sand, coarse aggregate, and timber will be required.
3. Choose good materials. Wash sand and coarse aggregate if necessary.
4. Construct your mixing-board (for small jobs) and make your measuring-boxes if the size of job warrants it.
5. Construct the "forms" and place them in position.
6. Do not guess at quantities—measure them.
7. Do not use too much water, or too little.
8. Do not mix too large a batch at one time.
9. Mix the materials thoroughly.
10. Place the concrete in position within 20 or 30 minutes of mixing.
11. Tamp it well and spade the edges.
12. Protect the finished concrete from sun and wind and keep the surface damp for ten days.
13. Do not remove the forms until the concrete is sufficiently hard.
14. For reinforced work ensure that the reinforcement steel and the formwork are securely fixed. A daily inspection of these should be made before work starts.

Useful Data

1 cu. ft. of cement (loose) weighs 90 lb. (approx.).
1 cu. ft. of water weighs 62·4 lb. (approx.).
1 cu. ft. of concrete weighs 112–140 lb. (approx.).
1 cu. ft. = 1,728 cu. in. = 6·25 gallons (approx.).
1 cu. yd. = 27 cu. ft., or 21 bushels.
1 (English) ton = 2,240 lb. or 20 cwt.
1 gallon of pure water at 62° F. weighs 10 lb.
1 ton of pure water at 62° F. = 35·97 cu. ft.

A contractor's wheelbarrow holds about $\frac{1}{10}$th cu. yd.

1 cu. yd. of earth or clay in the ground increases to about 1·25 cu. yd. when dug.

1 cu. yd. of sand or gravel in the pit increases to about 1·5 cu. yd. when dug.

CHAPTER XV

MISCELLANEOUS

Concreting During Hot Weather

During hot weather certain precautions must be taken to prevent the surface drying too quickly.

When exposed to the hot sun the surface of the concrete may soon dry, whilst that below the surface will still be wet. This will cause cracking, so the surface must be kept constantly damp, and when it has set and hardened sufficiently, sand can be gently sprinkled on. The sand may then be damped and kept moist for ten to fourteen days.

Frost Precautions

Normally, concreting should never be carried out during frost or when the air temperature is within 2 degrees of freezing point.

If, however, frost develops when concreting is in progress and the work on hand must be completed, it will assist matters if the water used for the mix is warmed. Coke braziers may be placed near the heaps of sand and aggregate to warm them. The percentage of cement may also be increased slightly, or rapid-hardening cement can be used, but the adoption of either of these last recommendations will increase the cost of the work.

In no circumstances must frozen aggregate or sand be used.

" Smudge " fires spaced about the area of work will assist in warding off frost from that vicinity, especially if placed on the windward side. These may be formed by using coal (or coke) braziers and adding bits of damp turf and old used engine oil, so as to create smoke, which disperses frost.

Such precautions will "screen" the work until it sets and hardens.

If rapid-hardening cement be used, the period of curing the concrete may be reduced also.

Note.—Special Portland cements containing calcium chloride are now made for use during cold weather. The calcium chloride accelerates the rate of strength development, and thus reduces the time during which the concrete is susceptible to frost.

Protection of Newly Made Concrete from Ground Frost

Road slabs, floor slabs, etc., after being freshly made, and throughout their curing period, must be suitably protected. This is especially so in exposed areas during winter—when concreting may be possible during the daytime, but when night ground frosts are liable to occur.

As mentioned earlier, sand spread lightly over the concrete at nightfall will afford some protection, and is probably suitable for work begun and completed early in the day, but that finished later in the day undoubtedly will not withstand "sanding" (nor covering with hessian canvas).

In such cases supports should be provided of sufficient height to carry timber battens, reinforcement steel, etc., spanning (or bridging) the new work and without sagging to touch the work when finally hessian canvas, or tarpaulin covers are placed on top. The covers should be laid flat and evenly, since cases have occurred when night frost has eventually turned to rain, which drenches the covers, thereby increasing their weight, and causes sagging to occur in places which may then press on to the new concrete and damage the surface.

If hollow "pockets" are permitted to develop in the covers during heavy rain, when the covers become saturated there is often a tendency for "drips" to occur, thereby affecting seriously the concrete surface below, since constant dripping through the covers will wash hollows in the concrete.

Close supervision should always be given to the covering down of such work, or damage may result, and care must be taken to ensure that the covers do not contain any tears or even small holes through which the rain can drip.

The sides and ends of the covers must also be either tied or weighted down, as a safeguard against wind, which causes them to be blown about, thus damaging the wet concrete surface. This is especially necessary for all roadworks, aerodrome runways, etc., in exposed areas.

Pointing and Repairing Damaged Concrete

Although concrete, after setting and thoroughly hardening, is rock hard, occasions may arise in which structures (walls, etc.) may be damaged by collision.

In such cases it is advisable to chip away all loose material and expose the "raw" concrete. This surface should next be well damped—as a precaution against absorption when the new concrete is later applied. This can be effected by using a water-can with sprinkler rose attached, hosing it, or by a bucket of water and a brush.

Provided the damage to the concrete is relatively small, it can be repaired by pointing, or filling up the cracks with a mortar made from cement, well-graded sand, and sufficient water to make the mortar into a stiff paste.

Here the tendency—especially for the inexperienced user—is to make the mortar too rich, owing to the impression that richness gives strength, but such practice should be treated with caution, since unless carefully cured, contraction cracks (hair cracks) in the new work are liable to develop, and this may later cause disintegration. It is preferable, therefore, to make the mix only *slightly* richer than the original concrete.

Should the damage to the wall be of a large nature, and exposing the reinforcements, these should be thoroughly wire-brushed to clean off any rust, before applying the new concrete. This is especially necessary if the damage is of long standing.

If the damage be a " chunk " of concrete knocked off a wall corner, it may be necessary to fix temporary shuttering, after thoroughly cleaning and damping the area.

The inner surfaces of the shuttering should be oiled to prevent the concrete adhering, and the new concrete should be poured from the top of the shutter position.

During the pouring operation the concrete should be well rammed.

If the damage be deep, it may be necessary to add some small aggregate to the new concrete (or mortar). The size of aggregate used will depend on the size of the damaged part.

In these cases it is advisable also to leave the shuttering projecting slightly, so that the finished concrete will be " proud " or project slightly from the original facing.

After the removal of the shutters and when the concrete has hardened, the projecting portion can be ground flush either by using a hand-type emery stone or a power-operated grinding-wheel disc-grinder.

In all cases of repairing or " pointing " damaged concrete it should be followed up by suitable curing, immediately after the shuttering has been dismantled.

For vertical or inclined surfaces this can best be effected by fixing hessian canvas adjacent to the concrete " patch " and by keeping it damp for three or four days.

For repairing a damaged floor area the foregoing principles may be applied, but after well cleaning away all broken concrete and thoroughly damping the area, sometimes a *thin* coating of cement grout (neat cement and water) is brushed lightly over the area, prior to applying the new concrete.

This, however, must be performed with care, to avoid over-richness, which may cause disintegration instead of better " knitting " to the existing concrete.

Fixings in Concrete

Although wherever possible it is best to fix anchor bolts, rag-bolts, etc., in the concrete during its casting process,

this is not always possible. Occasions often arise where fixings have to be made in existing concrete walls, etc.

Special tools—drills, "jumpers", and chisels—are used for making holes in concrete. These tools have specially hardened and toughened points which stand up well to the duty they are called upon to perform. The holes may be made by using one of the special tools such as "Rawlplug"

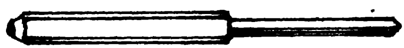

FIG. 160.—"PHILPLUG" SOLID FORGED JUMPER

(trade term) or "Philplug" (trade term). Two types of the latter make are shown in Figs. 160 and 161, and are known as "jumpers". They are used as a chisel—in conjunction with a hand hammer—but during use and during the striking by the hammer the tool should be rotated.

Quite neat holes can be formed in concrete by these means, after which bolts (or screws) may be grouted in position.

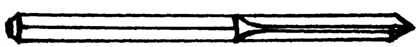

FIG. 161.—"PHILPLUG" JUNIOR JUMPER

However, a better fixing can be obtained by using one of the special inserts, such as "Philplug", "Rawlplug" or other well-known proprietary makes. The inserts are placed or driven into the hole and the screw is then screwed into the insert.

These special inserts can be used to advantage when making pre-cast concrete units, which require attachments, since the inserts then bond into the concrete ready for later fixing of attachments, brackets, screws, etc.

These special "Philplug" inserts are now used extensively for concrete railway sleepers for fixing the railscrews to the "chairs".

A compound known as "Philplug Screwfix is sold, where-

by, after making a hole in concrete for a screw, all that is required is to moisten a small quantity of Screwfix and roll into plug foam. This is inserted and rammed well into the hole, and pierced before finally inserting the screw. The compound sets in a few minutes and provides a very efficient fixing.

"Drill hammers" such as the "Kango" and "Rawlplug" (trade terms) are now available for attachment to

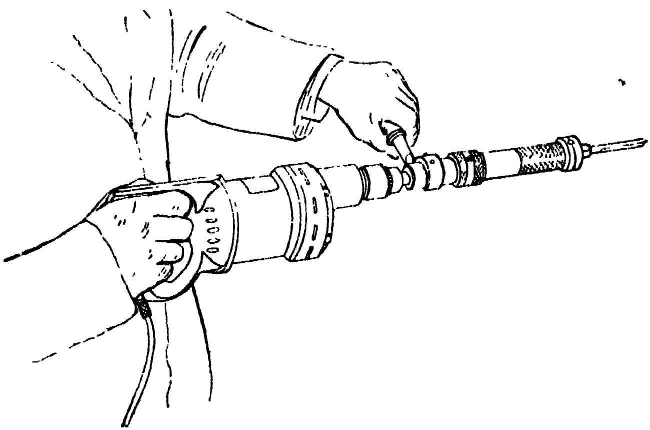

FIG. 162.—"RAWLPLUG"-TYPE DRILL-HAMMER ATTACHED TO AN ELECTRIC DRILL

small hand-type electric drills and by their use holes can be rapidly formed. These tools provide a combined rotary and striking action for forming the holes, and are very efficient and easy to use.

The drill hammer fits into the $\frac{1}{4}$-in (minimum) chuck of any small electric drill—such as "Wolf" or "Black & Decker" (trade terms).

A whole range of "Rawldrills" or "bits" is available from $\frac{1}{8}$ in. up to $\frac{3}{8}$ in. in diameter.

Fig. 162 shows the drill hammer in use and attached to a small electric drill.

A special type of anchor-bolt used for fixings is the " Philbolt " shown in Fig. 163. From this it will be seen that a lead " spreader " is used in conjunction with a malleable iron wedge and the nut.

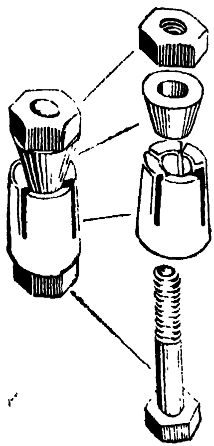

FIG. 163.—" PHILBOLT "

Waterproof Pit and Tank Construction

Although well-made concrete, using good hard aggregate, may be 99 per cent. waterproof, probably no concrete is 100 per cent. waterproof.

For concrete tank or pit construction, where a high degree of impermeability is essential, the concrete should be of as dense a composition as possible, and well-graded, hard aggregate must be used. In addition, it is usual to " render " the surfaces which come into contact with the water (or fluid). For rendering work, asphalt, bitumen, or pitch may be used.

Concrete tanks for holding water usually have their inner surfaces treated with asphalt, and concrete pits of high-class construction are usually made " double-walled " with a layer of asphalt, bitumen, etc., in between the walls to make them absolutely water-tight.

This type of construction is essential for large concrete tanks below ground level, such as fire reservoirs used during the war, swimming-baths, etc. This is especially so where a water "head" is concerned and where seepage from adjacent ground occurs.

Special attention must also be paid to construction joints, expansion joints, etc. These are frequently of the dove-tail type, having "Ruberoid" placed in between the joint, and in addition the joint is sometimes coated with bitumen or asphalt, as an extra precaution.

When lining tanks with asphalt, if difficulty is experienced in getting the asphalt to adhere to smooth concrete surfaces, a preliminary coat of pitch will assist matters.

Although many brands of waterproofing compounds are sold for mixing with the concrete to provide impermeability, in most cases the use of the compounds tends to weaken slightly the strength of the resulting concrete.

The compounds may be useful for small jobs, and are no doubt excellent for mixing with cement mortar to form waterproof renderings on outside walls of buildings, etc., but the most satisfactory way to construct waterproof pits or tanks below ground is by the double-shell or wall method (see Fig. 164).

In this case the concrete is made to withstand the stresses involved, and the asphalt placed between the walls takes care of the waterproofing.

For jobs of minor importance, and in order to reduce construction costs, it may be necessary only to render (by asphalt) the outside of the walls and floor, since this material, if effectively applied, will then prevent the ingress of water, while the concrete provides the mechanical strength (see Fig. 165).

In either type of construction both walls and floor concrete should be reinforced.

For the single-shell type with asphalt as the rendering material, to construct the floor a layer of tarred felt or Ruberoid should be placed first on the earth before asphalt-

ing is performed, or it may be only necessary to asphalt around the joints of "laps" of the Ruberoid.

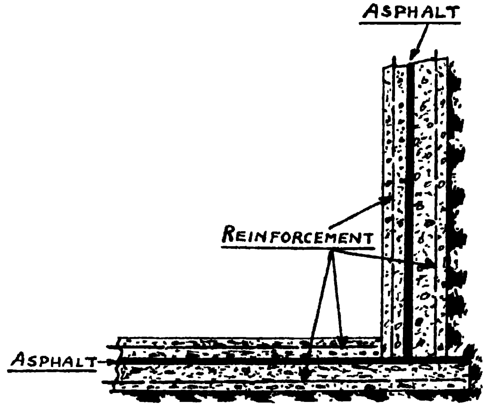

FIG. 164.—DOUBLE SHELL TANK CONSTRUCTION

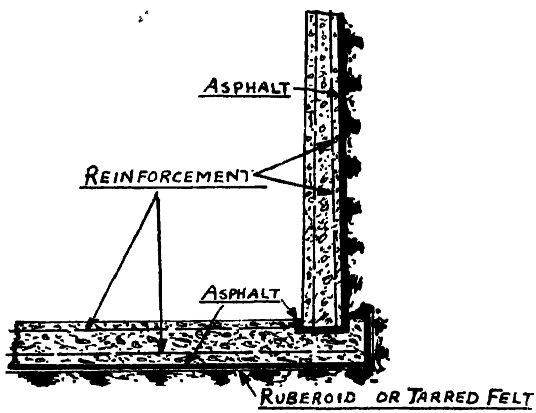

FIG. 165.—SINGLE SHELL TANK CONSTRUCTION

Before any attempt is made at construction of a tank below ground level, all possible information should be obtained regarding the water table, nature of subsoil, etc.,

and provision must be made for suitable pumping arrangements should water be encountered during excavation.

It will assist matters during excavation if a sump hole is dug outside the construction area but BELOW the floor level, so that seepage will be induced into the sump, thereby maintaining the excavation reasonably dry. This is an important factor where excavation must cease at the end of a day's work and where seepage may occur during the night.

It is an advantage also to connect (by a drain) the floor excavation level and the sump hole, in order to retain a reasonably dry floor during the construction period.

CHAPTER XVI

DOMESTIC CONCRETING FOR AMATEURS

General

Some persons may be interested in carrying out small concrete jobs for the house or garden, both as a matter of economy and where the work is too small to justify employing a contractor.

Moreover, many of the tools used for the home or garden will be found suitable for concrete work.

One of the chief essentials for the amateur is that he must have suitable dry storage facilities to store his cement, since much of his work will no doubt be performed at week-ends, during holidays, or in other spare time, with long intervals between in which cement stored in paper sacks is liable to absorb moisture—which is detrimental.

Such items as garden paths, edging, steps for a sunken garden, garage floor, coal-storage bins, walls, gate- and fence-posts, goldfish pools, lily-pools, etc., can be satisfactorily constructed if certain precautions are taken.

Since the handling of cement or concrete is " harsh " to the hands, persons accustomed only to clerical and similar work will find it an advantage to wear rubber gloves for concreting. After use, the gloves must be washed to remove all traces of cement, thereby preventing them from setting hard.

It will also be found advisable to wear gum-boots for both mixing and placing the concrete.

For most garden paths a suitable slab thickness will be 3 or 4 in. for 21- or 24-in.-wide paths, but in certain cases, where in daily use for the passage of a baby's pram to the garden, the path should be 2 ft. 3 in. or 2 ft. 6 in. wide.

Tools Required

These will depend on the type of job contemplated, but the following will be ample for average work, such as a path or garage floor : two or three buckets, two shovels, one spade, one wheelbarrow, one carpenter's saw, one trowel, one water-can with rose sprinkler, a 2-ft. measuring rule, mixing-board, or large steel sheet (unless a clean concrete or tarmac floor is available on which to mix the materials), an iron bar (for ramming) about 1-in. diameter by 2 ft. 6 in. long, timber straight edge, setting-out line, and spirit level (see Figs. 3, 6, and 7 for tool illustrations).

Materials

Portland Cement: in 1-cwt. paper sacks (ordinary grade).

All-in Ballast: containing sand in suitable proportions and well graded.

Wood boards of about 5 or 6 in. by 1 in. thick for shuttering and wood pegs to secure the boards.

Note.—All-in ballast or shingle is recommended for the amateur in order to simplify the mixing. "All-in" ballast is a shingle which contains approximately the correct percentage of graded sand.

A suitable mix, therefore, for concrete paths, etc., will be 1 part of cement to 6 or 8 equal parts of ballast, but since the mixing is to be performed by hand, 6 parts of ballast should be used to provide for any irregular mixing.

Mixing

Having provided a suitable clean surface on which to mix—either a hard floor, board, or steel sheet—place six buckets of ballast on it and spread it out evenly.

Next sprinkle one bucketful of cement evenly over the ballast, and mix thoroughly by turning the heap over and over by shovelling. Mixing should be continued until the material shows a uniform colour throughout. It is an advantage to have two operators working from each side of

the heap; the object being to turn the material over until every particle of aggregate is coated by the cement.

Then, and only then, should water be added, and it should be applied from a water-can having a rose spray.

The water must be sprinkled evenly and sparingly over the material, and during its application the heap should be turned over frequently, to obtain a uniform mix. The quantity of water used should only be sufficient to obtain a plastic, workable mix. Any excess is detrimental.

Moreover, if too much water is used, when the concrete is later placed in the shuttering (or formwork) and is rammed to compact it, the liquid rises to the top and escapes between the shutter boards, carrying with it particles of cement, thus losing its benefit. Since cement is by far the most expensive ingredient, it is thus uneconomical.

However, on the other hand, sufficient water must be added to permit efficient hydration for the cement.

In order to obtain some indication of the suitability of the mix, a bucketful of concrete may be taken by filling it in three equal portions and ramming each portion well during the filling; screed off level and deposit the contents on to a hard, dry, flat surface by inverting the bucket. The wet concrete will then "slump" or splay out. Measure the height of the heap as compared with the height of the bucket. If the bucket be 12 in. high and the heap has fallen to a height of say 10 in. or 10½ in., that would be called a 2-in. or 1½-in. "slump", and should be suitable for the work on hand.

Note.—When mixing concrete it may appear quite stiff, but on being placed in the work and rammed it may be found entirely suitable, so the beginner must not be tempted to make his mix too wet at the start.

Water should never be added to concrete after it has been deposited in the shuttering. Should the concrete when placed in the shutters appear too dry and be difficult to ram or "work", it is preferable to make the next mix slightly wetter and deposit it and mix well with that already placed in the shutters so as to even up matters.

Although in this example 6 buckets of ballast to 1 bucket of cement were suggested, double or treble these quantities may be used, provided the mixing area (or board) is large enough for these larger quantities.

In general, the thickness of concrete recommended for amateur-made structures is slightly in excess of that required for professionally made structures. This is to compensate for any irregularities in the mix, ramming, shuttering, etc., since the amateur has not the facilities available as used for mechanically vibrating concrete, nor for the accurate placing of steel reinforcement, etc., as performed by a professional contractor.

Garden Path Construction

All turf, weeds, etc., should be removed; this can preferably be done by skimming the ground with a spade, so as to shave off the top surface without disturbing the lower ground. Provided the ground is quite firm, and does not contain any soft spots, edging-boards can be placed and pegged in position according to the width of path. The pegs should be spaced about 2 ft. 6 in. to 3 ft. pitch on alternate sides of each edge-board. (The inner pegs must be withdrawn later when the concrete is placed (Fig. 92).)

The width of boards will depend on the thickness of the path; for a 3-in. thick path 21-in. wide, boards of 4 or 5 in. width will be suitable, since the lower edges should be driven into recesses formed in the ground to retain them.

Note.—If it is desired to form bends in the path to suit any existing garden lay-out, these can be effected by using thinner and more pliable boards and pegging at closer intervals, thereby straining the boards to the desired curve.

Should any soft spots exist in the ground, they should be excavated and filled with rubble, broken brick, or similar materials, and the material must be rammed solid, or the concrete may subsequently settle and crack.

Having fixed the edge-boards and checked them for level

and alignment, concreting may proceed. For small jobs the concrete can be carried in buckets, but a wheelbarrow will be an advantage for larger work, or if the distance from the mixing site is great.

It is essential to place the concrete as soon as possible after it has been mixed, since it will begin to set. In no case should the time between mixing and placing exceed half an hour.

After placing the wet concrete between the edge-boards it should be well rammed and roughly levelled with a spade or shovel. For ramming a 1-in.-diameter steel bar or piece of wood, about 1 in. by 2 ft. 6 in. long will be suitable.

It is during this ramming action that, if the concrete is too wet, watery scum will work upwards and float on top; this is called "LAITANCE", and unless removed will later disintegrate or peel off. Should laitance occur, it must be removed and replaced by drier concrete.

When a suitable area of concrete has been placed, well rammed and levelled with a spade, it should be "screeded" by placing a timber straight edge (on edge) over the work and resting it on both edge-boards. The screed-board should be moved gently to and fro with a sawing action to procure a smooth and level finish (Fig. 93).

It is preferable to ensure that the concrete, after ramming, is left higher than the edge-boards to enable any surplus to be screeded off, thereby ensuring a solid slab. Should any hollows occur in the concrete surface during the screeding, however, they should be filled up and the area screeded again.

Further placing of the concrete can then proceed, and be screeded and finished in due course; but a large area should never be left too long before screeding and finishing off, because of the risk of its setting.

When the concrete has finally set and hardened sufficiently, the edge-boards should be gently removed and the slab edges banked up with soil.

If it is desired to round off or bevel the edges of the

concrete slab (which is preferable in order to prevent the sharp corners being subsequently knocked off by the passage of pedestrians), the bevelling should be performed by trowelling immediately after the edge-boards have been removed and before the concrete has hardened completely (see Fig. 92). This involves earlier removal of the boards, and greater care should be exercised in so doing to prevent damage being done to the slab edges.

In order to prevent the wet concrete sticking to the boards, during their fixing the inner faces should be lime washed, or oiled with a special oil sold for the purpose.

Curing

When a suitable area of path has been screeded and finished off, the surface should be kept damp for at least three or four days. This is especially necessary during hot weather (or drying winds) in order to prevent the surface drying before the inner core has matured.

This curing can be effected by lightly sprinkling occasionally with water from a water-can fitted with a fine rose-spray, or, better still—when concrete has hardened sufficiently—covering with hessian canvas and maintaining it in a damp condition.

"Cheecol" (Trade Term) Process

Another form of path construction—and incidentally a quite simple one—is by the "Cheecol" process.

The method consists of, after having fixed the formwork (or shutters), as described previously, depositing large stones, broken brick, etc., in the trench and up to the level of the shutters.

A liquid grout is then made by mixing cement, sand, Cheecol, and water into a fairly thin paste; the grout is then poured over the stones and brushed into the interstices by using a stiff broom. The surface is then tamped and finally screeded off. The shutters can be removed after twenty-four hours and used for further work (Fig. 166).

Stones or broken brick used for this method should never be smaller than 1 in., and the largest should be not more than HALF the path-slab thickness. It is important, however, that the stones be reasonably clean.

In order to procure an attractive finish, coloured cement may be used if so desired.

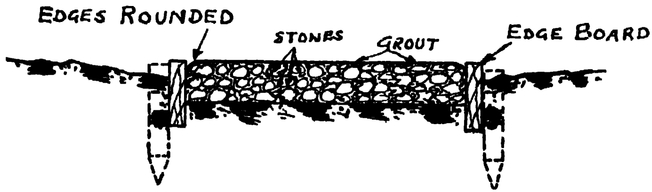

FIG. 166.—" CHEECOL " GROUTED PATH CONSTRUCTION

Proportions of Materials

To form the grout:

1 cwt. of cement (ordinary grade).
2–2½ cu. ft. sand (damp).
7–8 gallons clean water.
¼ pint Standard " Cheecol ".

Note.—The mix should be just fluid enough to run freely into the spaces between the coarse aggregate (stones).

Method of Mixing

Place the water in a tub or tank, add the Cheecol; next add the cement, and finally the sand. Thoroughly stir the mixture until no lumps are left.

It is advisable occasionally to stir the mixture to prevent settlement when batches are being taken from the tank for use. After mixing a quantity of the grout it should be used within half an hour.

Placing of Grout

Using buckets, or suchlike, convey the grout to the site and pour over the stones until it reaches the top and is level

with the shutters, thereby completely covering all the stones. Finish off by tamping and screeding.

If a smooth finish to the concrete is required, ½-in. to ¾-in. stone chippings may be sprinkled on the surface after grouting and lightly tamped in, or gently brushed in.

Finally, curing should be performed, as described earlier.

Crazy Paving Concrete Paths

For this type of path the slabs should be laid on a course of damp sand which has previously been levelled. A mixture of cement-sand grout (1 part of cement to 1 part of sand), with sufficient water to form a paste, is used for jointing, and it is preferable to pour a little grout on the sand and then to place the slab.

This procedure, in addition to providing a better bond with the sand, forces the surplus grout to the slab edges, where it forms mortar for the joint of the adjacent slab.

After a number of slabs have been laid, levelled, and jointed, the joints can be trimmed or pointed up flush by trowelling. This gives a neater joint than by brushing the grout over the joints.

Broken paving-stones from demolition work can often be bought cheaply, and make excellent crazy paving for paths.

Concrete Edging for Gardens

Continuous edging may be constructed in a manner similar to that previously described for garden paths, but by placing the edge-boards closer together. A suitable distance between the inner faces of the boards will be 2 in. for plain concrete, but if steel wire mesh is used as a reinforcement 1½-in. thick concrete should suffice.

For edging the depth should be from 7 to 9 in. by leaving, say, 3 or 4 in. projecting out of the ground (Fig. 167). The concrete for such work should be composed of aggregate whose size does not exceed ¾ in. for a 2-in.-thick edging, and the mix should be not leaner than 1 part of cement to 6 parts of ballast aggregate. For 1½-in. edging, having mesh

reinforcement placed vertically on edge in the centre, the largest aggregate should not exceed $\frac{3}{8}$ in. in size.

A 1 to 6 mix should also be employed. It is important also that the inner faces of the shuttering be well oiled or limewashed.

A trench of suitable size must be dug to accommodate the edge shuttering and concrete thickness. Distance pieces should be packed between the boards, and pegs used on the boards' outer sides to retain them in position; as work proceeds and the concrete is placed, the distance pieces can be withdrawn slightly ahead of the concreting.

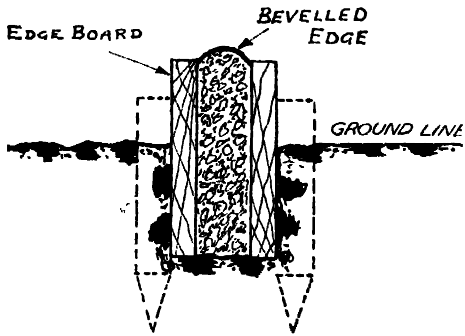

FIG. 167.—CONCRETE EDGING FOR GARDENS

When the concrete has finally set and hardened, the earth should be rammed well down on both sides of the crevice to provide support.

Curing should be performed as described earlier.

Pre-Cast Concrete Edging

More attractive designs of garden edging can be made by the amateur by the pre-cast method, in the form of slabs or tiles (see Fig. 168).

Suitable mould-boxes can be made from pieces of scrap timber whose thickness is such that warping will be pre-

vented when used under wet conditions. For the sizes of slabs suggested the mould base should be about 2 in. thick and preferably in one piece. Two side-pieces should be

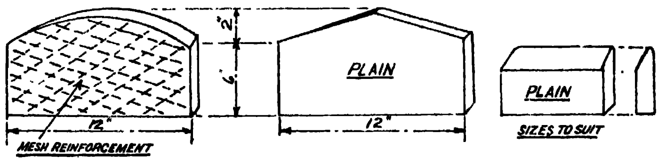

FIG. 168.—TYPICAL PRE-CAST GARDEN EDGING UNITS

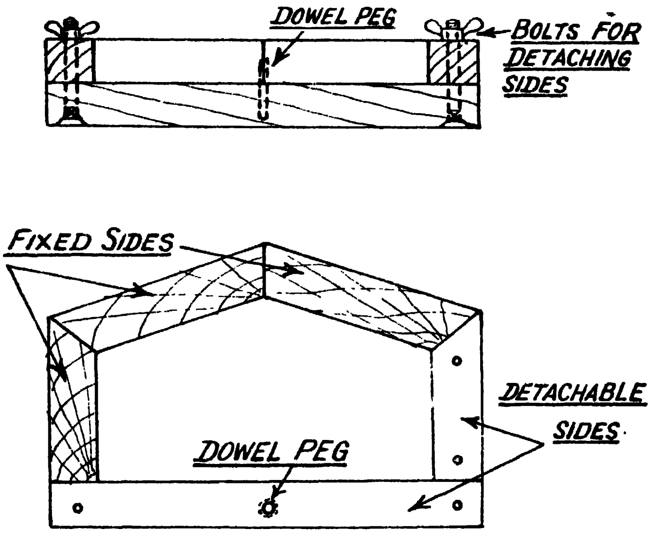

FIG. 169.—TYPICAL MOULD-BOX FOR PRE-CAST UNIT

easily detachable, thereby providing facilities for extracting the moulded slabs.

For this purpose galvanized steel or brass bolts fitted with wing-nuts are preferable (see Fig. 169).

It will also be an advantage to make two or three

mould-boxes to increase output, or the slabs can be made at leisure and stored for future use by employing one box.

A fairly dry mix should be used, and the largest size of aggregate should not exceed $\frac{5}{8}$ in. for plain concrete and $\frac{1}{4}$ in. for reinforced.

Having prepared the moulds, oiled their faces, and ensured that the bolts are tight, place the concrete and ram well into the corners; it is preferable to add the concrete in two or three layers, well ramming each.

The mould should be filled to overflowing, after which it should be screeded level by using a piece of wood edgeways and gently tamping the concrete, to procure thorough compaction. Under favourable conditions, and if a good dry mix has been used, the slab should be ready for withdrawing in from half to one day from casting. After withdrawing it should be stored and kept damp for at least seven days before use.

For service, the edging slabs can be used unjointed, or, if desired, jointed by "cement grout"—a paste formed of equal parts of cement and sand with sufficient water to give plasticity.

For straight paths the slabs may be laid without jointing, but if used on curves they should certainly be jointed.

An advantage of this pre-cast method is that the slabs can be made in any spare time, or in wet weather under cover when normal garden work cannot be done outside.

Concreting a Floor of Existing Garage

Having excavated the floor for a suitable slab thickness of, say, 3 or 4 in., and levelled the surface reasonably well, the concrete can be laid. If, however, the surface is very dry, it is advisable to damp it lightly with a watering-can to prevent the ground absorbing moisture from the concrete.

Start laying the concrete at the rear end and spread it out to the desired thickness. It should be well rammed by means of a steel bar or a spade. When an area of sufficient size has been laid and rammed, it should be levelled and

finished with a spade or trowel. From time to time a straight edge can be placed over the surface as a check to guide the levelling operation.

Work should proceed on these lines until the whole area has been completed.

It is preferable to provide a slight fall in the floor-surface level from rear to front of the garage for drainage purposes, for if this is not done, when a car is driven in during heavy rain, the rain collects, instead of draining away outside.

Moreover, it is advisable to form a more defined slope or ramp from the front of the garage to 2 or 3 ft. away from the doors, to prevent rain accumulating at the door-bases.

When laying the concrete it is helpful, as a guide for thickness, to place bricks at intervals on the ground until concreting reaches those positions, when they can be removed. This is very convenient for a 3-in.-thick floor slab.

Concreting a Floor for a New Garage

Assuming the ground to be level and clear of weeds, turf, etc., the area should be pegged out and edge-boards erected to form the shuttering. The boards should be levelled and held in position by driving pegs into the ground on both sides, similar to the method described for paths. For floor areas of, say, 16 ft. by 8 ft. up to 20 ft. by 10 ft. a slab thickness of 3 or 4 in. will be suitable.

If bolts are to be used for securing the garage upright bases, provision can be made for them by placing square timber blocks at the required positions. These should be either greased or limewashed to facilitate withdrawal later when the concrete has set. Alternatively, the base-bolts may be concreted in during the placing of the wet concrete, but in such cases the precise positions must be accurately ascertained, since with this method no provision is left for lateral or vertical adjustment of the bolts during erection.

Having previously greased or limewashed the inner faces of the edge-boards, concreting may begin; a suitable mix, if using plain concrete, will be 1 part of cement to 6 or 8

parts of graded ballast or shingle. The largest size of aggregate (stones in the ballast) should not exceed 1¼ in.

If, however, the Cheecol process of concreting is to be used, stones of up to 2 in. in size should be spread over the whole area and filled level with the top of the shuttering. Cheecol grout—as described earlier—should then be poured over the stones so as to completely cover them, and should be level with the top of the boards. The mixture should then be brushed in so as to thoroughly coat all the stones. A stout timber straight edge should be used as a screed-board for tamping and screeding the surface.

Should any hollows develop in the surface, they should immediately be filled in by adding further stones and grout.

Note.—The slab thickness already given is applicable to a plain garage structure, but if one be contemplated incorporating a heavy steel lifting beam to form the door lintel, with a view to attaching a pulley-block for engine changing, etc., the slab thickness in the vicinity of both door-posts should be increased. This is because the additional load on the lifting beam will be transmitted directly to the upright bases positioned at the corners of the slab, where they are weakest, and if the slab thickness is not increased, cracks or breakage may result.

Pit in Floor (Fig. 170)

If a pit in the floor is contemplated, it should be positioned near the door end (but not too near, on account of rain drifting beneath the doors), since more daylight is available there.

After excavating the pit, the floor should be concreted, and a drainage sump about 6 in. deep should be provided in one corner into which oil, water, etc., can collect, thereby maintaining the remainder of the floor clean and dry. This sump can be emptied as and when required by ladling, thereby saving the expense of elaborate drainage work beneath the whole garage floor.

Should the nature of the ground be such that water occurs at the pit-floor level, before concreting the pit slab, bitumastic sheeting, Ruberoid, or similar material should first be laid, and the ends turned upwards into the wall positions. After concreting the pit floor and sump, and when the concrete has hardened sufficiently, shuttering for the walls should be erected and securely fixed in position.

The concrete used for the pit floor and walls should also contain a suitable waterproof compound, of which many proprietary brands are sold for the purpose.

At the top of the walls a recess should be provided in which to place timber planks to form a cover.

The wall concrete must be well rammed during its placing,

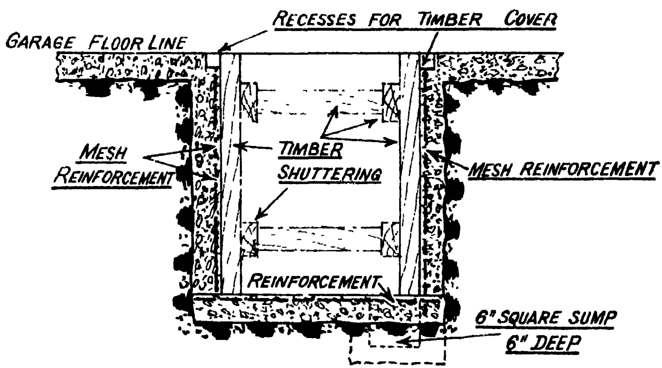

FIG. 170.—PIT FOR GARAGE FLOOR

and the percentage of cement should be increased slightly to procure a good dense concrete.

Floor and walls of 2½ or 3 in. thickness will be ample for a pit of, say, 3 ft. long by 2 ft. wide by 2 ft. 6 in. or 3 ft. deep, which size will be found suitable in most domestic garages, and mesh reinforcement should be incorporated in both floor and walls in the positions indicated in the sketch (Fig. 170).

Concrete Coal-bin

A domestic coal-bin can be made in concrete fairly easily by the average handy-man.

Pre-cast concrete blocks joined by cement mortar may be used for the construction, but provided sufficient timber for shuttering is available, the cast " in-situ " type will be more substantial and satisfactory.

First a base slab should be made of, say, 2½ or 3-in.-thick concrete. It should be levelled off by floating over or screeding. The area for the wall thicknesses should then be marked out, but before the slab has set and hardened, pieces of ¼-in. diameter iron bar about 7 or 9 in. long should be placed vertically in position at the centre line of the position in which the walls are to be formed. These bars are to form " keys " for bonding the wall concrete to the slab—and also to form reinforcement.

After the base slab has set and hardened, timber shuttering must be erected to form the outer faces of the walls. The shuttering must be secured rigidly in position by battens and struts, etc. Next a box-type frame must be made for the inner wall-face shuttering.

For a small bin having a coal capacity of, say, 3 or 4 cwt., a wall thickness of 2½ in. will suffice. Wood blocks of 2½ in. thick, to form distance pieces can be placed at suitable intervals and heights between the inner and outer shuttering and wedged in position. The inner shuttering must be rigidly secured so as to withstand the pressure when the wet concrete is later poured and rammed.

The inner shuttering frame must be made readily detachable so that it can be easily removed after the walls have set and hardened. These shutters should therefore be screwed or bolted together, instead of being nailed.

After checking both internal and external shuttering for alignment and rigidity, the inner faces must be greased or limewashed to prevent the concrete adhering.

A suitable concrete mix will be 1 part of cement to 5 or 6 parts of good clean all-in ballast, but the largest size of

stones in the ballast must not exceed $\frac{3}{4}$ in., and a fairly dry mix should be aimed at.

Holes should be drilled through the shuttering at positions in the front wall to provide for bolts for the slide doors, etc. Into these holes either steel tubes can be placed (and concreted in), or greased bars can be fixed to form templates for the holes; these are later withdrawn, thereby leaving suitable holes in the concrete for the bolts (see Fig. 171).

A simple type of lid can be made of timber covered with tarred felt, Ruberoid, or similar material. The lid may merely rest on the top walls, and thus be readily removable for filling the bin, or it may be fitted with hinges (in which case bolt-holes must be provided when concreting the rear wall) and a hasp can be fitted to the front for a padlock.

However, if a concrete top or lid be desired, it will be preferable for the amateur to make it as a pre-cast unit. This can be accomplished by making a wooden mould-box of suitable shape and size in which to cast the wet concrete, on similar lines to the method described for path-edging blocks.

It will be necessary, however, to reinforce the lid slab by using either B.R.C. steel fabric or EXPANDED metal fabric and steel rods placed longitudinally and transversely as shown.

The slab thickness will depend on the size of bin, but in no case should it be less than $2\frac{1}{4}$ in., and the reinforcing mesh should be placed in a position $\frac{3}{4}$ in. up from the LOWER face, and the $\frac{1}{4}$-in. steel bars placed on the mesh or fabric.

If a concrete lid is decided on, steel dowel-pegs should be concreted in the walls and should project $1\frac{3}{4}$ in. from the face.

Corresponding holes must be made in the lid-slab to take the dowel-pegs, but these holes should be much larger in diameter than the bolts. Moreover, holes must also be provided for the door-slide framework.

The lid concrete should be rammed well during its placing and should be well cured by maintaining it in a damp condition for three or four days. Great care must be exercised in removing the lid-slab from its mould, and no

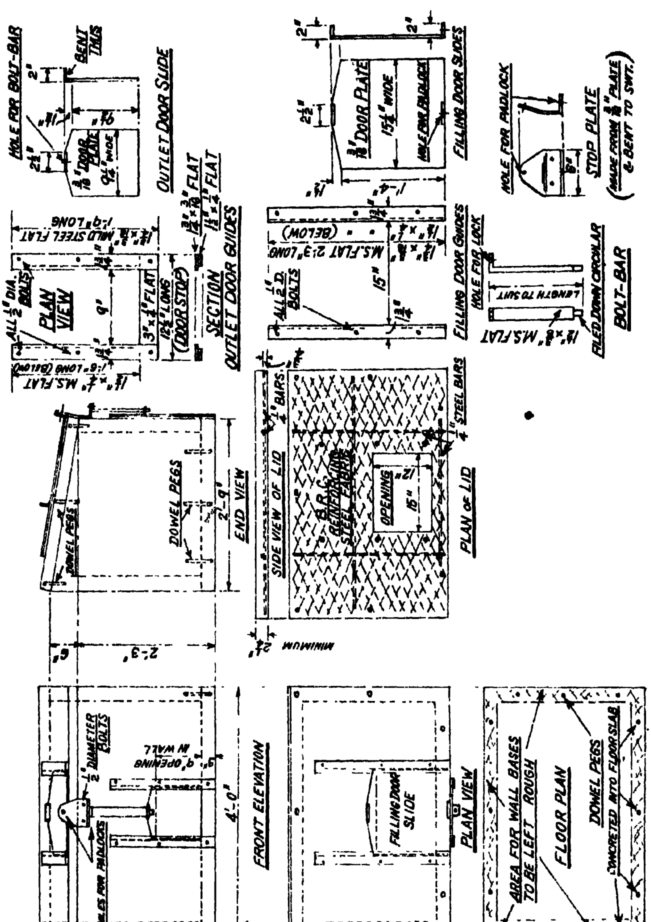

FIG. 171.—TYPICAL DESIGN FOR DOMESTIC COAL-BIN (APPROXIMATE CAPACITY 7 TO 8 CWT.)

attempt should be made to extract it for at least four days after casting.

An alternative construction for the concrete lid is to cast it in two units, leaving a space in the centre for the feed-door slide. In this method steel-mesh reinforcement should be used, as indicated previously, but the thickness of the slabs can be reduced to 2 in. for a small coal-bin of, say, 3 ft. 6 in. by 2 ft. floor area. Dowel-peg holes should also be provided, and after laying the slabs in position on the bin the dowel-peg holes should be grouted in.

It will be preferable to use a slightly richer mix for the lid-slab; say 1 part of cement to 4 parts of ballast, and for a 2-in. thick lid-slab the largest size of aggregate should be ½ in.

The dowel-pegs should *not* project through the concrete lid, but only into it. The holes in the lid for the pegs must be sufficiently large to allow for adjustment of the lid, and when final alignment has been made grout should be applied, thereby securing the lid to the bin. The horizontal joint may then be floated over with a trowel and grout.

Details of the filling and outlet doors, frames and fittings are given, and these are shown made of mild steel, whose sizes have been determined by taking into account outdoor use in all weathers. It will be advisable to paint all the door-fittings to prolong their life.

Unless the reader has some experience of metal-work and facilities for cutting and drilling, etc., it will be preferable for him to purchase the fittings locally and have them made to his requirements. As an alternative to mild steel, aluminium may be used, but the initial cost will be slightly higher. Since aluminium does not rust, it may be beneficial in the long run, and the weight of the slide doors will be reduced, and the aluminium need not be so thick as steel.

Provision has been made for padlocking both doors, and after removal of the bolt-bar from the outlet door, the latter can be held open by attaching a small chain-hook to the lower part of the stop plate.

All bolts should be fitted from the outside, thereby having the nuts on the inside of the bin.

A coal-bin made on the lines of the foregoing description should last a lifetime, and will require practically no maintenance whatever.

Garden Fence or Gate-posts

Concrete posts of rectangular cross-section can be made with a minimum of trouble; those of tapered formation require a little more skill and experience.

A rectangular timber mould should be made of suitable thickness to prevent warping. One side and one end should be detachable to facilitate extraction of the finished product. All inner faces of the mould must be treated either with the special oil or grease sold for the purpose or by limewashing.

It will be preferable to use a richer concrete mix; say 1 part of cement to 4 parts of ballast or shingle. Moreover, it is essential to reinforce the posts by placing a steel rod of about $\frac{3}{16}$ or $\frac{1}{4}$ in. diameter vertically near each corner position; the rods must be held rigidly in position by wire links and by tying them to the longitudinal corner rods with thin, soft binding wire (Fig. 121).

The concrete must be well rammed in between the reinforcements. Small-sized aggregate must be used, so as to facilitate penetration between the steel work.

For posts of $3\frac{1}{2}$- or 4-in. square section, the largest aggregate should not exceed $\frac{3}{8}$ in.

Note.—Further details of fence construction are given in Chapter 8 (Pre-cast Units).

Goldfish Pool (or Lily-Pond) Construction

The chief essentials for the construction of these are that they must be water-tight and suitable provision must be made for changing the water by arranging drain-off piping, or, for very small ponds, by ladling out the water.

For small pools a dense, well-made concrete with the

addition of one of the well-known water-proofing compounds should suffice. Larger-sized ponds, in addition to these precautions, may require some type of waterproof lining, such as asphalt, pitch, bitumen, etc. But *great care* must be exercised in using some types of lining for fish-pools, since some materials are liable to kill the fish.

Pools of medium or large size must have a drain-off tap and pipe service laid beneath the floor level, and at the connection with the pool-base a suitable gauze-type filter of either copper or galvanized-iron construction should be provided to prevent sediment entering the drain.

For all types of water containing structures a well-compacted mix of 1 part cement, 1½ parts of graded sand, and 3 parts of graded coarse aggregate is recommended; the waterproofing compound should be used according to the maker's instructions. Coloured cement may be used if desired.

For oval (or egg-shaped) pools the surface finish is best performed by trowelling or floating.

GLOSSARY OF TERMS

Aggregate.—Strictly speaking this means all particles of sand, broken stone, or gravel, etc., used in making concrete. The term is often loosely used to denote all particles larger than $\frac{3}{16}$ in., in which case "coarse aggregate" is more correct.

Ballast.—Shingle dredged from river-beds, etc.

Batch.—The quantity of concrete mixed at one time.

Bulking.—The swelling up of sand caused by moisture. Sand as delivered for the job is usually damp and contains about one-third of a gallon of water per cu. ft. In this condition its volume is about 30 per cent. greater than it would be if bone dry or dripping wet.

Cement Mortar.—A mixture of Portland cement, sand, and water.

Concrete.—A mixture of Portland cement, sand, coarse aggregate, and water.

Cribbing.—Same as formwork.

Curing.—Concrete becomes hard by the chemical combination of cement and water, during which process it is necessary to prevent as far as possible evaporation of the water from the surface of the concrete; this is called "curing", and is accomplished by covering the concrete, as soon as it can be done without damaging the surface, with damp cloths, wet straw, wet sand, etc., kept wet by sprinkling, or by immersing in water. Concrete made with ordinary Portland cement should be cured for at least ten days when normal methods are employed. The curing of pre-cast objects can be accelerated by steaming at a certain temperature for about twenty-four hours in special chambers. Rapid-hardening cement cures more quickly than ordinary Portland cement.

Final Set.—Occurs when the concrete has definitely set but has not yet hardened sufficiently for the formwork to be removed, or to be used for the purpose intended. In normal weather the final set with ordinary Portland cement occurs about three hours after mixing in summer, and four hours in winter.

Floating.—Smoothing the surface of newly placed concrete or mortar with a flat piece of wood provided with a handle, or with a steel trowel. A steel trowel works the fine material to the surface and gives a smooth finish. The process, however, if overdone, may cause fine hair-cracks to appear in the surface later on.

FORMWORK.—Moulds formed of boards or metal sheets, etc., into which concrete is placed immediately after mixing, and left to set.

GRADED.—The proportioning of particles of material from the largest to the smallest in such a way that the least volume of voids (or empty spaces) is left.

GROUT.—A mixture of cement and water of a consistency about that of cream.

HARDENING.—The strength of concrete under favourable curing conditions increases with age. Hardening is very rapid in the early stages, but continues more slowly for an indefinite period amounting to years.

INITIAL SET.—Concrete should not be disturbed after this has occurred, which with ordinary Portland cement takes place between half-an-hour and one hour after mixing.

KNOCKING UP.—Breaking up and remixing concrete that has begun to set. This should not be allowed.

LAITANCE.—A watery "scum" which may form at the top of concrete in which too much water has been used, or when too much floating or trowelling has been done. If laitance is not removed the upper portion of the concrete will be porous.

MASS CONCRETE.—Concrete in which there is no reinforcement.

PLACING.—The process of putting concrete which has just been mixed into the position in which it is required to set.

POURING.—Same as placing.

PUNNING.—Same as ramming.

RAMMING.—The process of consolidating concrete, or thoroughly working it down so that it will fill up all places in the formwork, etc., intended for it, and leave no empty spaces. Usually done with a blunt piece of wood or a tamper.

REINFORCED CONCRETE.—Concrete in which steel rods or wire mesh, etc., has been embedded at suitable places to increase the strength in tension.

RENDERING.—Adding a thin layer of cement mortar to the surface of concrete or brickwork, etc. The surface to be rendered must be rough to form a key, and wet to prevent absorption of water from the mortar.

RODDING.—Same as ramming, but done with a bar of iron, which can pass between reinforcement where a thicker tool could not.

SAND.—All particles of aggregate from the finest up to $\frac{3}{16}$ in.

SCREEDING.—Obtaining a level surface at the correct height by means of a piece of wood or metal having a straight edge. The screed is rested at both ends on guides, or on the top of the formwork, and worked to and fro with a sawing motion over the surface of the concrete.

SEGREGATE.—The separating out of particles of different sizes. If a well-graded mixture is shaken too much the larger particles may tend to sink to the bottom, thus spoiling the grading, with the undesirable result that the composition of the concrete will vary at different places in the work.

SHUTTERING.—Same as formwork.

SLICING.—Same as spading.

SLUMP.—A measure of workability.

SPADING.—Similar to rodding, but done with a narrow spade close to the formwork. This works the fine material to the sides of the work and produces a smooth finish. It should not be overdone (*see* Floating).

STRIKING.—Dismantling and removal of formwork.

VOIDS.—Empty spaces between separate particles.

TAMPING.—Same as ramming.

TROWELLING.—Smoothing over the surface of concrete or cement mortar renderings with a flat steel trowel. This produces a very smooth surface, but should be done even less than smoothing with a wooden tool (see Floating).

WATER-CEMENT RATIO.—Other things being equal, the strength of concrete is governed by the amount of water used with the cement. Provided the mixture is workable, the less water used the better the concrete.

WORKABILITY.—A workable mixture is one of such consistency and degree of wetness that it can be placed in the forms readily, and which with spading or tamping will result in a dense concrete.

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BRITISH STANDARD SPECIFICATIONS

Relating to concrete materials, testing of materials, test apparatus, and concrete products.

	B.S.S. No.
Cements—	
Ordinary Portland and rapid-hardening Portland	12
Portland—blast-furnace	146
High-alumina	915
Low-heat Portland	1370
Aggregates—	
Foamed blast-furnace slag	877
Concrete aggregates and building sands from natural sources	882, 1198–1201
Air-cooled blast-furnace slag coarse aggregates	1047
Clinker aggregates for plain concrete	1165
Sizes of road-stones and chippings	63
Methods for sampling and testing mineral aggregates, sands, and fillers	812
Reinforcing Steel—	
Rolled steel bars and hard-drawn steel wire for concrete reinforcement	785
Cold twisted steel bars for concrete reinforcement	1144
Steel fabric for concrete reinforcement	1221
Mixers—	
Batch-type concrete mixers	1305
Sieves—	
Test sieves	410
Pigments—	
Pigments for colouring cement, magnesium oxychloride and concrete	1014
Precast Concrete—	
Precast concrete kerbs, channels, and quadrants	340
Precast concrete flags	368
Concrete plain roofing tiles and fittings	473
Precast concrete blocks	492, 728, 834 & 2028
Concrete interlocking roofing tiles	550

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